MAY • 1966
PRICE $1.00

ELECTRICAL CONSTRUCTION AND MAINTENANCE

WITH ELECTRICAL CONTRACTING

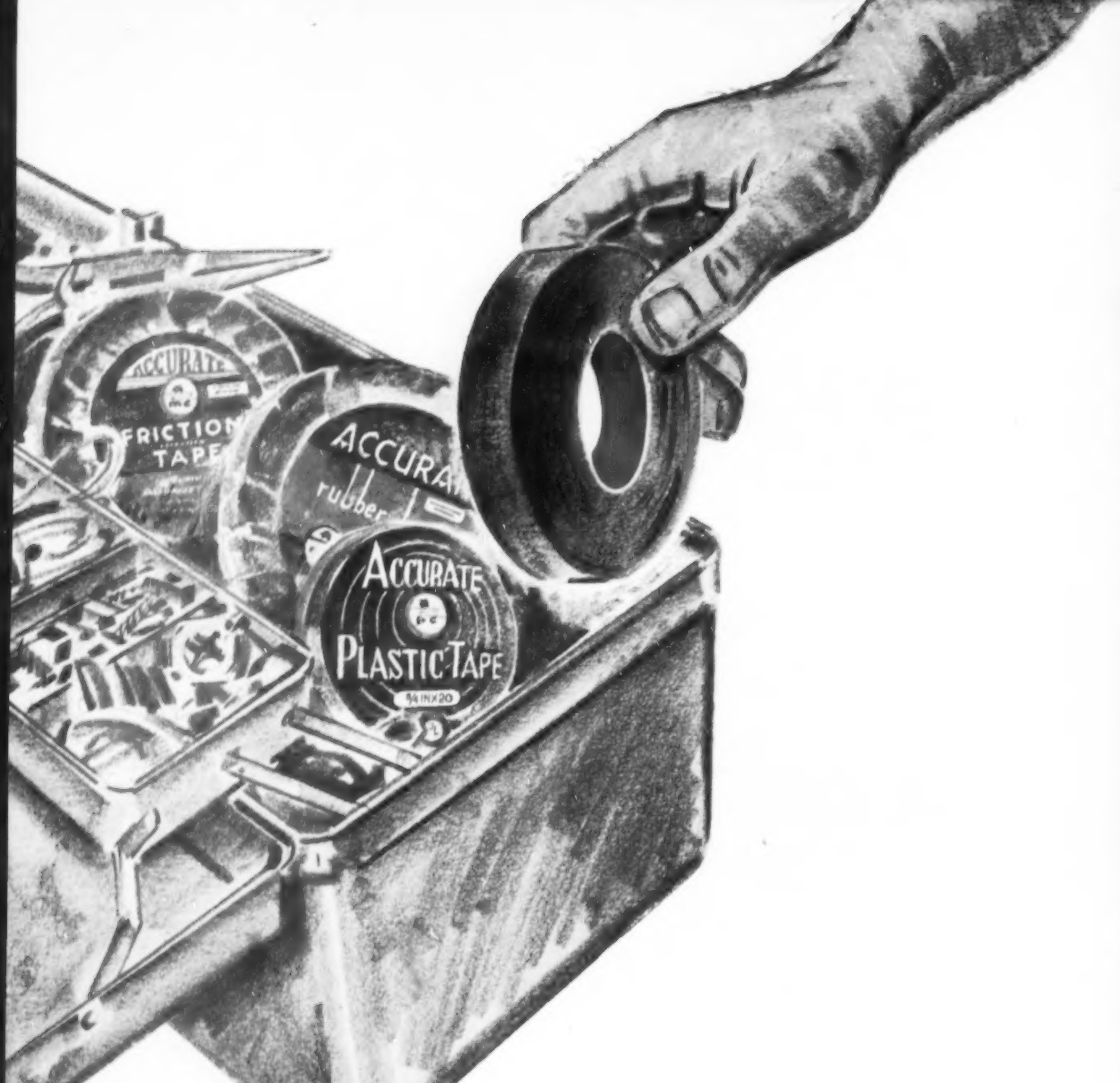
A FIRST!
IMPORTANT...
KEEP THIS
W.J.S.

Modern Electrical Systems Design

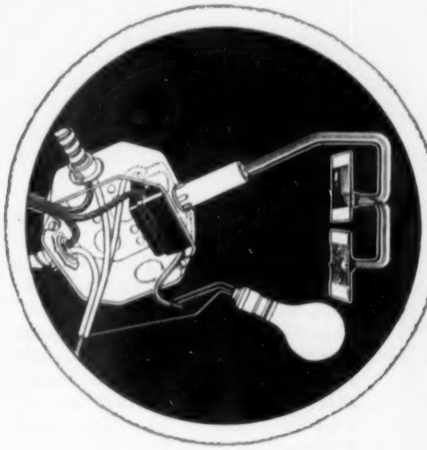
New, comprehensive, practical data on the design and layout of electrical systems for today's
- **commercial**
- **institutional**
- **industrial**
- **residential building**

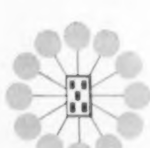
A McGRAW-HILL PUBLICATION

55TH YEAR


ACCURATE
FRICTION TAPE
rubber
ACCURATE
PLASTIC TAPE
3/4 IN X 20

NOW INSTALL 3-WAY SWITCHING IN HALF THE TIME...





and pocket 40% more profit. Great news for you! The REMCON low-voltage relay with its built-in transformer now makes it economically possible for you to give your customers silent 3-way and 4-way switching.

All you do is *match the 3 wires of each switch to the 3 wires of the silent* REMCON *relay.*

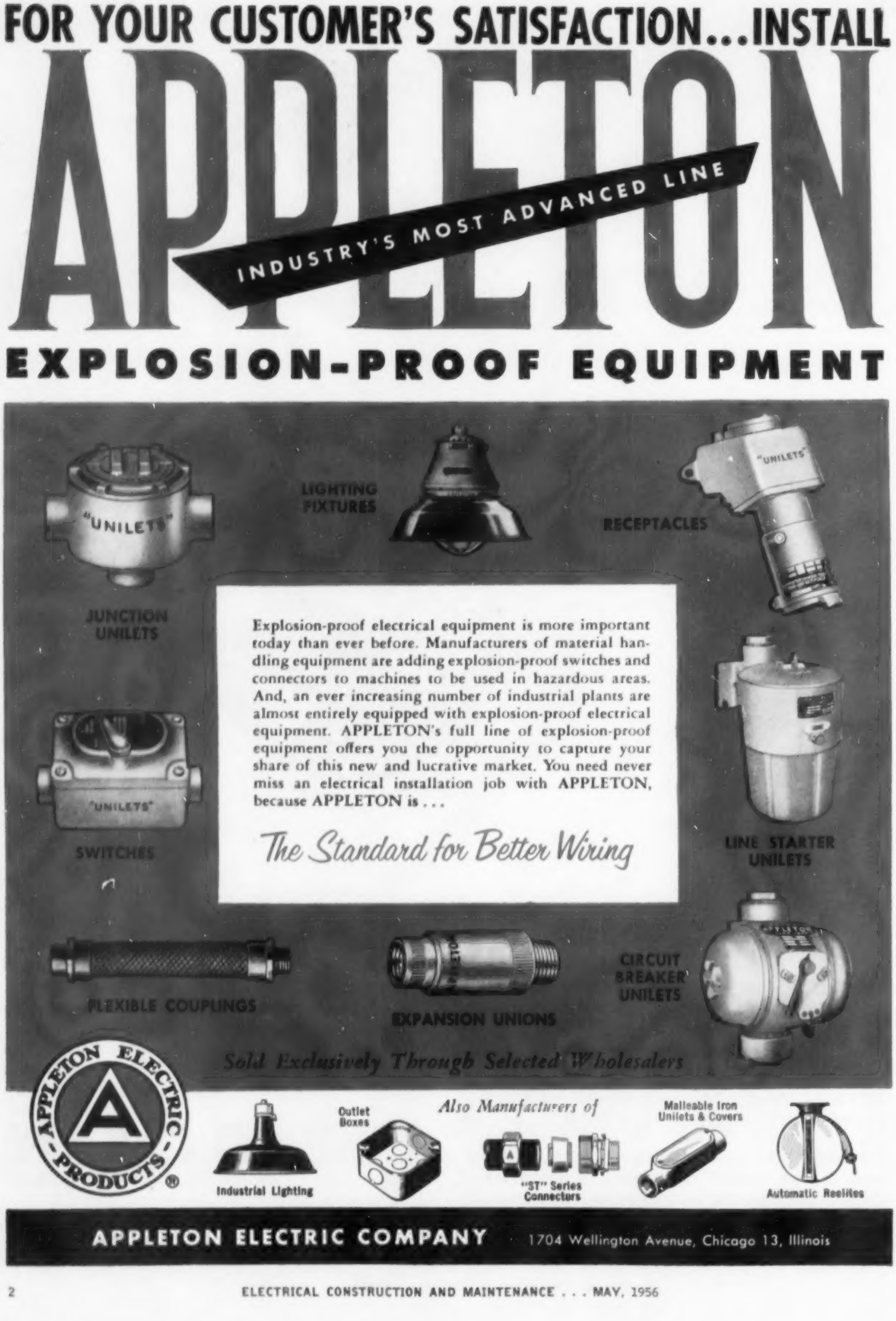
It's simple. It's fast. It's foolproof. REMCON eliminates working with armored cable on all switch legs. You use only light, pliable, low-voltage wire that's easy to handle and strip. With REMCON you not only save time, you also provide silent switching at no increase in cost of materials.

For every switching job...whether it be 3-way switching ... control of a single light from many switching points ... remote control of many lights and appliances from one switching point ... or a complete basement-to-attic remote control system ... always reach for REMCON.

REMCON

HIGH PROFITS FROM LOW VOLTAGE

REMCON DIVISION, PYRAMID INSTRUMENT CORPORATION, LYNBROOK, N. Y.


FOR YOUR CUSTOMER'S SATISFACTION...INSTALL
APPLETON
INDUSTRY'S MOST ADVANCED LINE
EXPLOSION-PROOF EQUIPMENT
"UNILETS"
JUNCTION UNILETS
LIGHTING FIXTURES
RECEPTACLES
"UNILETS"
Explosion-proof electrical equipment is more important today than ever before. Manufacturers of material handling equipment are adding explosion-proof switches and connectors to machines to be used in hazardous areas. And, an ever increasing number of industrial plants are almost entirely equipped with explosion-proof electrical equipment. APPLETON's full line of explosion-proof equipment offers you the opportunity to capture your share of this new and lucrative market. You need never miss an electrical installation job with APPLETON, because APPLETON is . . .
The Standard for Better Wiring
"UNILETS"
SWITCHES
LINE STARTER UNILETS
FLEXIBLE COUPLINGS
EXPANSION UNIONS
CIRCUIT BREAKER UNILETS
Sold Exclusively Through Selected Wholesalers
APPLETON ELECTRIC PRODUCTS
Also Manufacturers of
Industrial Lighting
Outlet Boxes
"ST" Series Connectors
Malleable Iron Unilets & Covers
Automatic Reelites
APPLETON ELECTRIC COMPANY
1704 Wellington Avenue, Chicago 13, Illinois

ELECTRICAL CONSTRUCTION AND MAINTENANCE

with which is consolidated Electrical Contracting, The Electragist and Electrical Record . . . Established 1901

Published for electrical contractors, industrial electricians, engineers, consultants, inspectors and motor shops. Covering engineering, installation, repair, maintenance and management, in the field of electrical construction and maintenance.

55th Year— MAY • 1956

Member of
AUDIT BUREAU OF CIRCULATIONS and ASSOCIATED BUSINESS PUBLICATIONS

Vol. 55, No. 5 May 1956

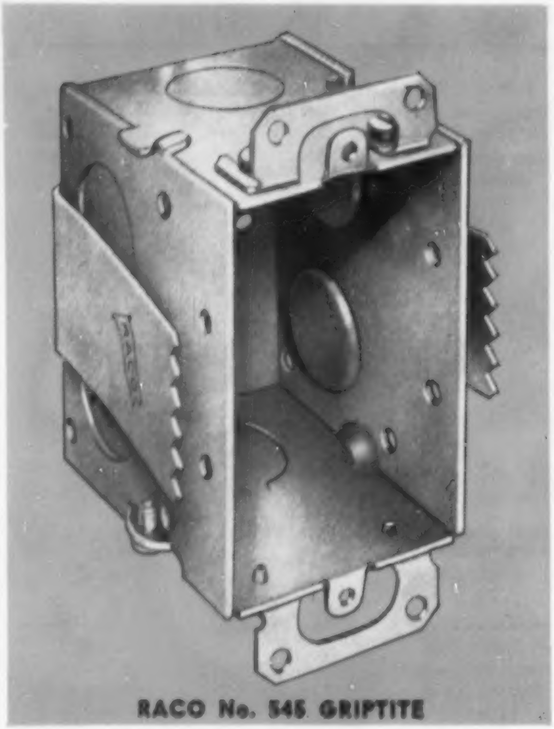
ELECTRICAL CONSTRUCTION and MAINTENANCE

Published monthly with an additional issue in September by McGraw-Hill Publishing Company, Inc. James H. McGraw (1860-1948), Founder. Executive, Editorial and Advertising Offices: **McGraw-Hill Building, 330 W. 42nd St., New York 36, N. Y.** Publication Office, 99-129 North Broadway, Albany 1, N. Y. Donald C. McGraw, President; Paul Montgomery, Executive Vice-President, Joseph A. Gerardi, Executive Vice-President, and Treasurer; John J. Cooke, Secretary; Nelson Bond, Executive Vice-President, Publications Division; Ralph B. Smith, Vice-President and Editorial Director; Joseph H. Allen, Vice-President and Director of Advertising Sales; J. E. Blackburn, Jr., Vice-President and Director of Circulation.

Subscriptions: Address correspondence to Electrical Construction and Maintenance—Subscription Service, 330 W. 42nd St., New York 36, N. Y. Allow one month for change of address.

Subscriptions are solicited only from persons engaged in electrical construction or electrical maintenance. Position and company connection must be indicated on subscription orders.

Single copies 35¢. Electrical Products Guide $2.50 to those in the electrical construction and maintenance industry. Subscription rates—United States and possessions, $3.00 a year; $4.00 for two years. Canada, $5.00 a year; $8.00 for two years. Other Western Hemisphere and Philippines, $10.00 for one year; $16.00 for two years. All other countries, $15.00 a year. Three-year rates, accepted on renewals only, are double the one-year rate. Entered as second class matter August 29, 1936 at the Post Office at Albany, N. Y., under act of Mar. 3, 1879. Printed in U. S. A.

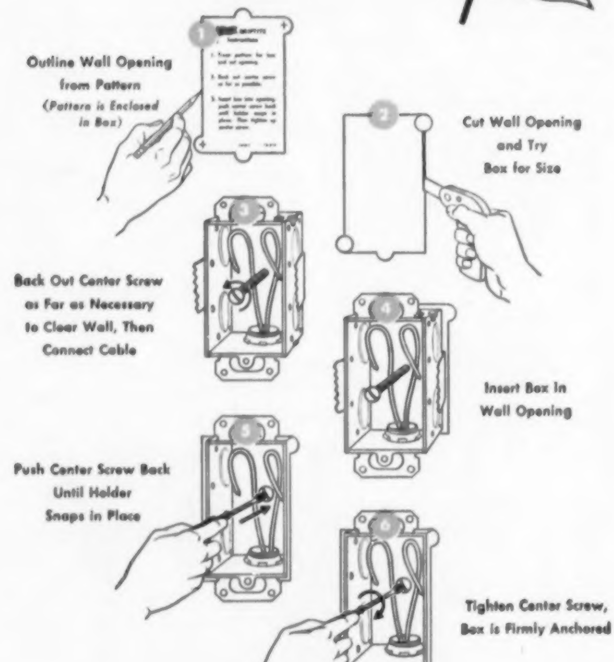


RACO No. 545 GRIPTITE

New RACO GRIPTITE BOX

Saves Time and Money On All "Old-Work" Installations

SIX EASY STEPS TO INSTALL



- ✓ EASIEST BOX TO SET IN PLACE
- ✓ FOR ANY TYPE OF WALL
- ✓ ONE-SCREW ADJUSTMENT
- ✓ ANCHORS SECURELY

The RACO Griptite Box takes less time to install, is easier to adjust, holds tighter than any other method of "old-work" installation. Made of heavy gauge metal . . . durably finished. Saves time and money . . . helps protect your profit margin on "hard-to-figure" old work installations.

WRITE TODAY FOR COMPLETE INFORMATION

"A RACO BOX FOR EVERY NEED"

ALL-STEEL EQUIPMENT INC. Aurora, Illinois

Washington Report

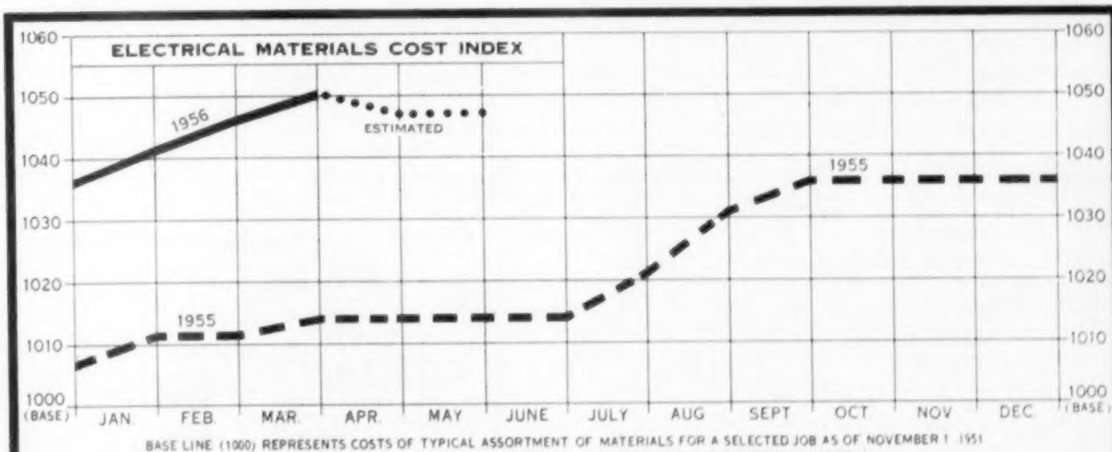
The overall level of business activity remains at a record high although several industries are operating below 1955 record peaks. Some of the more important economic factors are: Down—1st Q. auto production (18% from 1955); 1st Q. housing starts (15% from 1955); farm equipment production. Up—output of goods and services—GNP ($399 billion, up $23.7 billion in one year); industrial production (FRB index 142, up 7 points in year); personal income ($313.1 billion annual rate, up $19.9 billion in year); civilian employment (63.1 million in March, up 2.5 million in year); steel production (10.9 million tons in March, 31.9 million tons in 1st Q., up about 10% in year); electric power output (weekly average of about 11 billion kwhr, up an average 12% in one year); retail trade $15.8 billion in March, up from $14.7 billion in March 1955); and cost of living remained steady through February at BLS index of 114.6, a change of not more than .2 points for seven months.

Housing starts moved up seasonally to 96,000 units in March, 23% ahead of February's 78,000, for a first quarter 248,000 total. Volume was $3,175 million—5% below 1955's boom first quarter total.

HHFA Administrator Cole forecasts a total of 1,300,000 home starts for this year, despite the slow pace now being experienced. His forecast is based on an upswing in homebuilding during the last half of the year, a reversal of the 1955 pattern. Starts have trailed the year-earlier totals for the last seven consecutive months. However, except for 1955, the totals this year are still the biggest on record.

The letdown on housing (from 1955) is timely, in view of upward price trends, as it has temporarily helped to relieve the strain on supplies of raw materials and labor. But if home buyers get homes with more space, better provisions for TV viewing, design for quiet for parents, and other improvements (at resulting higher costs) which a "Women's Congress on Housing" sponsored recently by HHFA reported as what the American housewife wants in the home of the future, then dollar volume in homebuilding this year will undoubtedly break all records. In addition, Operation Home Improvement under U. S. Chamber of Commerce sponsorship and with Government's blessing, is plugging for a $10-billion residential remodeling and repair activity this year.

New building construction put in place in March was nearly $3 billion, up 10% over February and equal to last year's March record. Total for first quarter was $8.5 billion, surpassing last year's first quarter slightly.



BASE LINE (1000) REPRESENTS COSTS OF TYPICAL ASSORTMENT OF MATERIALS FOR A SELECTED JOB AS OF NOVEMBER 1 1951
INDEX POINTS REPRESENT VARIATION OF THESE SAME MATERIAL COSTS AS OF THE FIRST OF EACH MONTH
SOURCE - NATIONAL PRICE SERVICE CLEVELAND OHIO

THE SHORTAGE OF SCIENTISTS AND ENGINEERS:

How Critical Is It?

The United States is running into a serious shortage of scientists and engineers. There is no novelty in this observation. It has often been made in the last few years. And there has been mounting alarm about what this shortage may mean for both our national security and our prosperity.

There would be great novelty, however, if general agreement were attained on such important matters as the size of the shortage, the extent of the damage it threatens to inflict, and the best ways to eliminate it. The purpose of these editorials is not to provide this novelty, but to ventilate some of the key aspects of the shortage of scientists and engineers.

This first editorial in the series is designed to throw light on the over-all dimensions of the shortage. Others to follow will be addressed to such questions as:

- How serious is the threat to our economic well-being and to our national security?
- What needs to be done to prevent the shortage from becoming critical?

Rise Has Been Rapid

The problem is *not* that we have been producing a small number of engineers and scientists. Indeed, the number has risen sharply. We now have a working force of more than 600,000 engineers, over twice as many as the 286,000 there were in 1940. And we have about 250,000 scientists (chemists, physicists, biologists, geologists, mathematicians, etc.), compared to only 92,000 in 1940. About one in 148 persons in the labor force of 1940 was a scientist or engineer; today the ratio is about one in every 80.

In research and development work, where highly creative scientific minds are required, there has been fully as rapid a rise in employment of scientists and engineers. Fewer than 90,000 were employed in research and development fifteen years ago; the total now exceeds 200,000.

—But Not Rapid Enough

Despite this rapid increase in the number of scientists and engineers — at a rate much faster than the increase in the labor force as a whole — the needs of industry, government and education for technically trained people have risen even more sharply.

The principal reason for this mounting demand is the prodigious growth of research in the last 15 years. From a total of only about $900 million spent on all types of research in 1941, the annual expenditure rose to over $5 billion by 1953 (the latest estimate available). Over two-thirds of the research is done by private industry, mostly to develop new and better products and to find new and better methods of production. Most of the rest is performed by the government, largely to develop improved and inevitably more complex scientific weapons.

One aircraft company has found from its own experience that it required 17,000 engineering manhours to develop a typical fighter plane in 1940. The requirement is now about 1.4 million engineering manhours. Development of the typical fighter plane of 1960 will require well over 2 million engineering manhours.

In this dramatic example, the need for engineering services for a basic piece of military equipment soared 80 times in 15 years. It is an indication of why the demand for more and more technically trained men and women has outstripped even the imposing increase in scientific and engineering manpower of the last decade and a half.

Size of the Gap

Exactly how great the gap is between the available supply of scientists and engineers and the number required, it is impossible to say. In some instances technical talent undoubtedly could be better used than it is now. And part of the shortage might "disappear" if higher salaries had to be paid. (These questions will be discussed in later editorials.) But informed estimates of the approximate size of the gap can be given.

- According to the best available information, from estimates by the Engineers' Joint Council and the U. S. Bureau of Labor Statistics, **the minimum need for engineers from graduating classes is 40,000 each year for the next ten years.** Last year we graduated only 23,000 engineers, just about enough to cover replacement needs without allowing for any expansion of the number of active engineers. Projections made by the U. S. Office of Education indicate that we shall probably not have a class of 40,000—the *current* annual requirement —until 1963.
- According to Dr. Howard Meyerhoff, executive director of the Scientific Manpower Commission, **there is now a shortage of about 20,000 scientists.** Last year the number of doctoral degrees in the natural sciences, almost a prerequisite for research work, was only 5,000. Dr. Meyerhoff estimates that the shortage of scientists will rise another 30,000 by 1960.

More Needed As Teachers

Not all of the graduates with scientific and engineering training, furthermore, will work as scientists and engineers—that is, by performing research and giving it practical application. Such training is now necessary in many sales and management positions. And more of our technically trained men and women must remain in educational institutions as teachers if the quality of engineering and scientific education is to be maintained. A survey in 1954-55 by the National Education Association showed that, out of 277 universities, state colleges and large private colleges, nearly one-third *already* had unfilled vacancies in engineering and three-fourths had vacancies in physical sciences.

The dimensions of the shortage of scientists and engineers can be summarized as follows: **Despite a substantial rise in the trained manpower available, the needs of industry, the government and education have risen still faster. The best information indicates that, on the basis of current and anticipated needs, our recent yearly rates of production of slightly over 20,000 engineers and about 5,000 PhD's in natural sciences could be doubled without closing the gap entirely.**

The disturbing implications of this shortage for our national security and our prosperity and some practical suggestions for eliminating it will be the subjects of subsequent editorials in this series.

This is one of a series of editorials prepared by the McGraw-Hill Department of Economics to help increase public knowledge and understanding of important nationwide developments of particular concern to the business and professional community served by our industrial and technical publications.

Permission is freely extended to newspapers, groups or individuals to quote or reprint all or parts of the text.

Donald C McGraw

PRESIDENT

McGRAW-HILL PUBLISHING COMPANY, INC.

BULLDOG *Electrostrip*®

PATENTED

... brings new electrical convenience to homes, offices, buildings ... saves you time and trouble!

Please *all* of your customers ... save yourself headaches, too! You'll do both with new Electrostrip—the multi-outlet assembly that provides *movable* electric outlets every *inch along its length*. Your job estimates will be easy, quick and *accurate* ... installation a cinch. The strip mounts on any surface ... connects to any fixed outlet. There's no breaking into plaster; no wire fishing.

So, forget about outlet planning. With Electrostrip, outlets are twisted in where needed ... placed and spaced exactly where your customers want them. Neat and attractive, Electrostrip is perfect for every type of building. It's listed by U.L., rated at 20 amps and 125 volts A.C.

For details, see your electrical distributor or BullDog field engineer. Or write BullDog Electric Products Co., Detroit 32, Michigan.

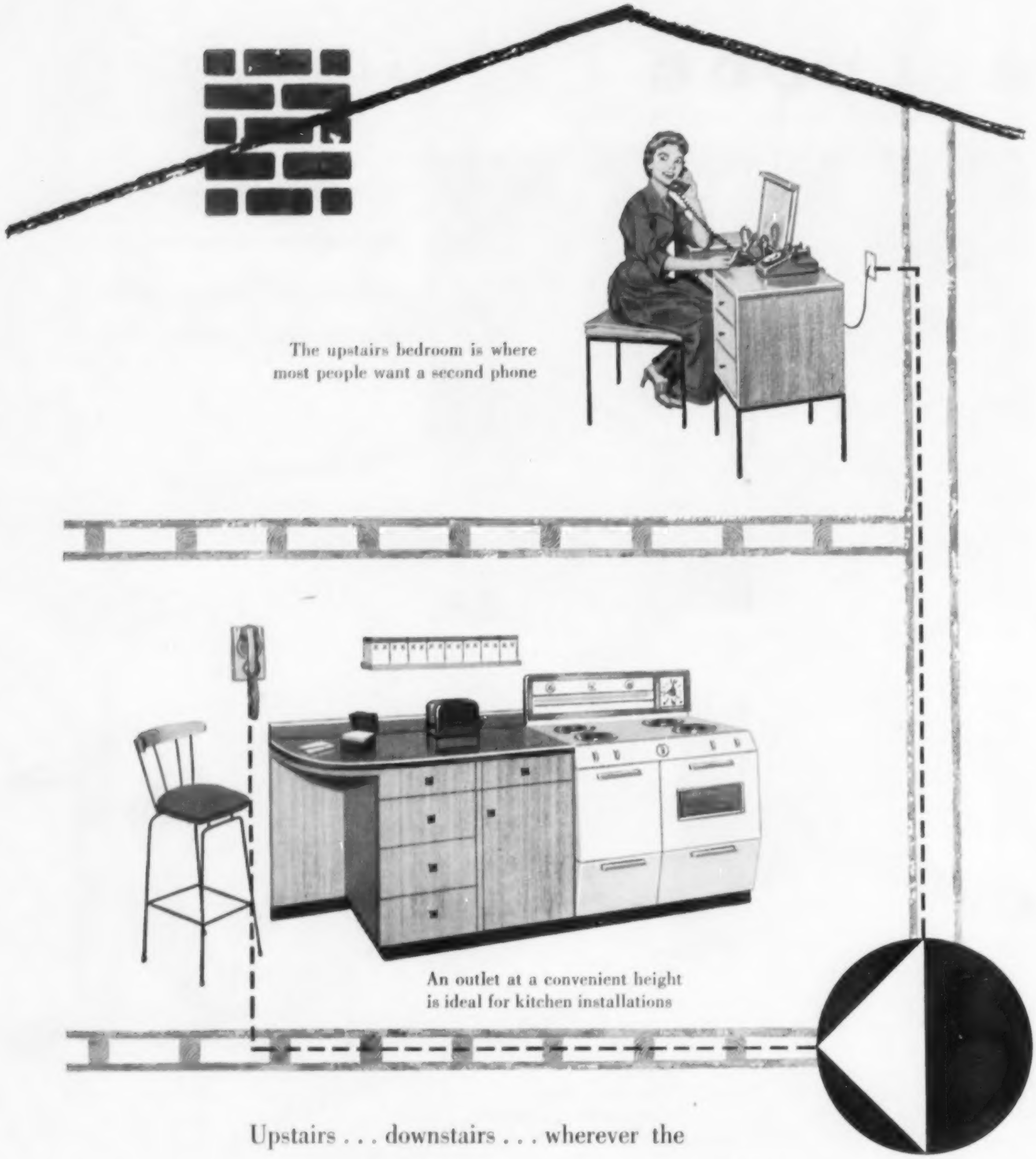
© BEPCO

IF IT'S NEW ... IF IT'S DIFFERENT ... IF IT'S BETTER ... IT'S **BULLDOG**

ELECTRIC PRODUCTS COMPANY

A Division of I-T-E Circuit Breaker Company

Export Division: 13 East 40th Street, New York 16, N.Y. • *In Canada:* BullDog Electric Products Co. (Canada) Ltd., 80 Clayson Road, Toronto 15, Ont.

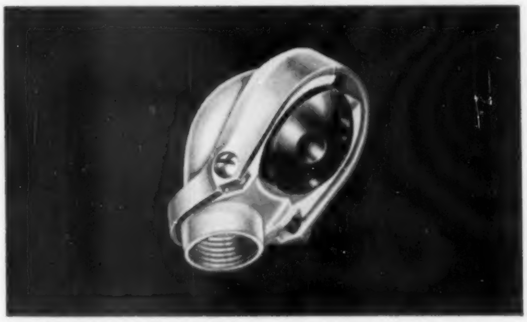


Upstairs . . . downstairs . . . wherever the
modern family sleeps, works, or plays,
good planning calls for built-in telephone outlets
. . . and concealed telephone wiring.

BELL TELEPHONE SYSTEM

Your Bell telephone company will be glad to help you work out economical concealed wiring installations. Just call your nearest business office and ask for *Architects and Builders Service*. For details on home telephone wiring, see Sweet's Light Construction File, 8i/Be. For commercial installations, Sweet's Architectural File, 32a/Be.

COMBINATION ENTRANCE CAPS Here's a real "2-in-1" entrance cap ... approved by Underwriters' Laboratories for both rigid conduit and EMT ... permits stocking of one cap for two purposes ... eliminates threading of rigid conduit. Comes in sizes from ½" to 2".



THREADED CONDUIT ENTRANCE CAPS Like most other Gedney entrance caps, this one is made of malleable iron to prevent breakage ... hot dip galvanized for maximum service life. Sizes range from ½" to 6".

ENTRANCE CAPS For S.E. Cables—with key hole mounting bracket. Easy to assemble—cable slips into cap and is securely held by clamping shoe. Has split insulator and well bushed holes. Overlapping cover protects cables from weather. As there is little strain on this fitting it is made of malleable iron.

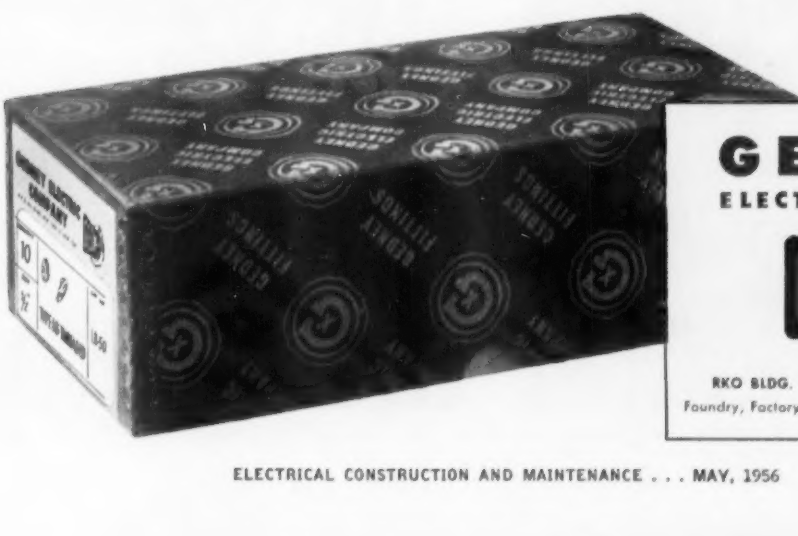
Cross the threshold to lower costs...with

GEDNEY ENTRANCE CAPS

Malleable Iron—Hot Dip Galvanized

THESE ENTRANCE CAPS install faster—and cut your *final* costs right down to rock bottom. Like all Gedney Fittings they're accurately machined and threaded...smooth finished, with no burrs or metal particles. On top of that, the Gedney line includes many improved design features that bring extra efficiency and labor savings. For fittings that bring today's lowest installed cost, specify Gedney!

GEDNEY FITTINGS FIT

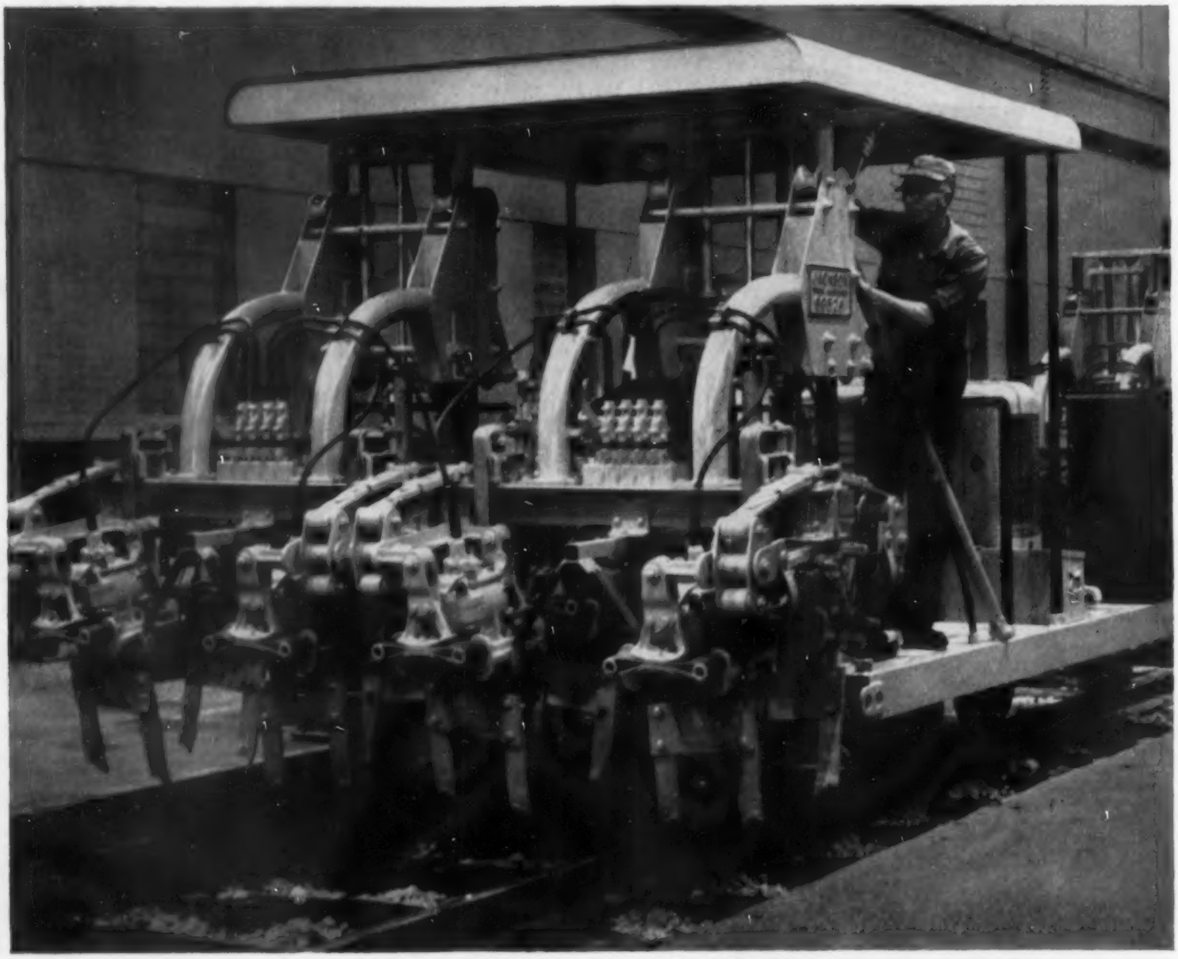


GEDNEY
ELECTRIC COMPANY

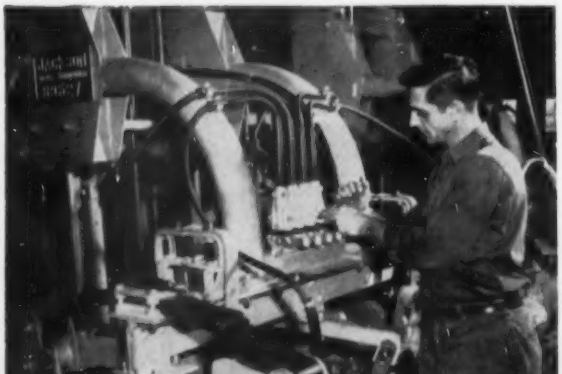
GEDNEY

RKO BLDG. • RADIO CITY • NEW YORK 20
Foundry, Factory and Shipping Point: Terryville, Conn.

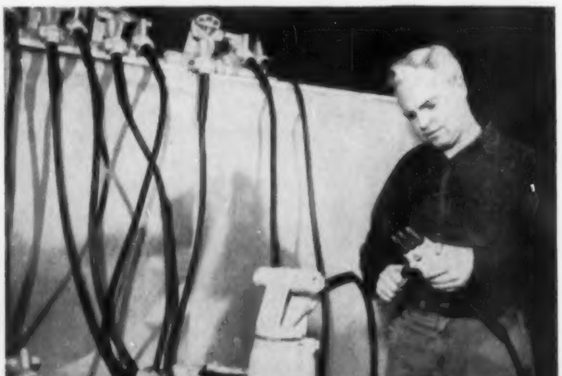
"Tiger Brand Amerclad is the most



The completely self-contained Jackson Track Maintainer.



Tightening connectors. Machine delivers 4500, 2-ton blows per minute.



Assembling leads. Each vibrator delivers ¾ ton blow.

durable cable we've ever used"

says **ELECTRIC TAMPER & EQUIPMENT CO., Ludington, Michigan**

MANY years ago, the executives at Electric Tamper & Equipment Co. found out that when railroads order a piece of machinery, they expect it to last a long time—without breakdowns. Since then, Electric Tamper has won a high place in industry by producing a line of the hardest-working, *toughest* track maintenance machines on the market.

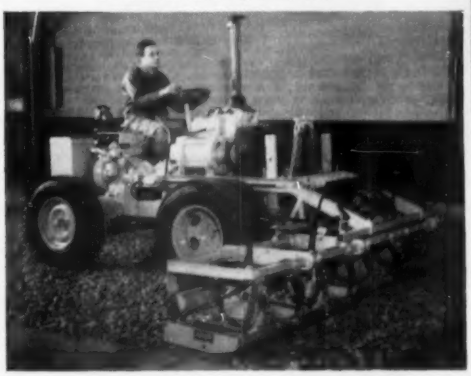
Leader of the line is the Jackson Track Maintainer, used for tamping ties. It has 8 powerful vibratory motors that drive 8 tamping assemblies. Each motor is powered with Tiger Brand Amerclad cable. The vibration and flexing (which are very severe) caused previous cable to crack until the jackets actually peeled away from the conductors. So they asked American Steel & Wire for advice.

Tiger Brand Amerclad was the solution. Finely stranded conductors soak up vibration and allow greater flexibility than ever before. The tough, well-cured jackets are impervious to oil, grease and the burning sun.

In the company's own words, "Tiger Brand cable is certainly superior to anything we have ever seen for this class of service. Its complete dependability under all service conditions has definitely helped us to maintain our good reputation in the field."

Do you want a *better* electrical cable—engineered for your equipment? Just call your American Steel & Wire representative.

The Jackson Multiple Compactor for consolidation of granular soil.



Hand Vibrospade. Cable usually drags on the ground.

Small compactor. See why they need durable cable?

AMERICAN STEEL & WIRE DIVISION, UNITED STATES STEEL, GENERAL OFFICES: CLEVELAND, OHIO
COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO, PACIFIC COAST DISTRIBUTORS · TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA., SOUTHERN DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS TIGER BRAND ELECTRICAL WIRE & CABLE

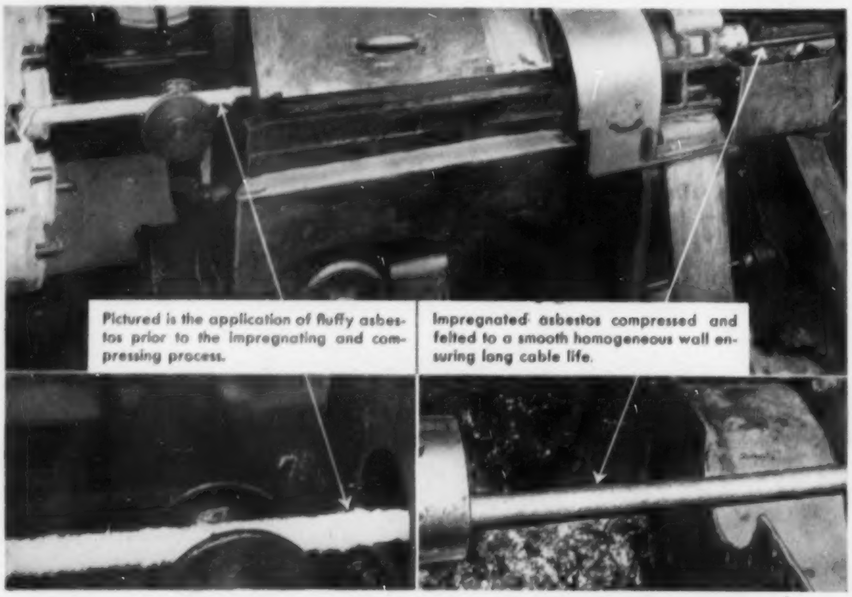
A STANDARD TIGER BRAND CABLE FOR EVERY SPECIAL JOB

- machine tool and building wire
- special purpose wire and cable
- asbestos wire and cable
- paper and varnished cambric cable
- aerial, underground and submarine cable
- shovel and dredge cable
- mold cured portable cord

USS

UNITED STATES STEEL

seamless FELTED ASBESTOS walls add up to long range economical service



Pictured is the application of fluffy asbestos prior to the impregnating and compressing process.

Impregnated asbestos compressed and felted to a smooth homogeneous wall ensuring long cable life.

look beneath the braid

. . . that's where quality begins

Long lasting, trouble-free circuit performance depends on the materials and construction of wire and cables. And a look under the braid shows why Rockbestos A.V.C. (N.E.C. Type AVA) is built to give longer service.

The two seamless, dense felted asbestos walls, compressed and thoroughly impregnated with selected compounds, seal the varnished cambric from heat and moisture.

Dielectric strength stays high under high ambient temperatures. Heat dissipation is uniform. The felted wall construction protects the varnished cambric from rupture in the sharpest bends.

HERE'S HOW YOU BENEFIT*

Get high dielectric values from Varnished Cambric because of its controlled application over seamless felted asbestos walls.

HIGH DIELECTRIC STRENGTH — minimum breakdown voltages for 600 and 1000 volt power cables — 15 KV.

MOISTURE RESISTANCE — same minimum dielectric breakdown — wet or dry — 15 KV on 600 and 1000 volt power cables.

RUGGED CONSTRUCTION — minimum breakdowns after bending tests — 15 KV for 600 and 1000 volt power cables all sizes.

CONTROLLED QUALITY — materials and workmanship and performance under rigid Quality Control.

CUTS MAINTENANCE COSTS — It won't bake brittle, crack or flow in high ambients . . . won't deteriorate with age, or rot when exposed to oil, grease or fumes.

The result: wire failures are eliminated; maintenance costs are held down; plant and equipment operation maintained at top level.

*Write for the test and construction specifications of Rockbestos A.V.C. (N.E.C. Type AVA) available in the new booklet, "Specification RSS-88."

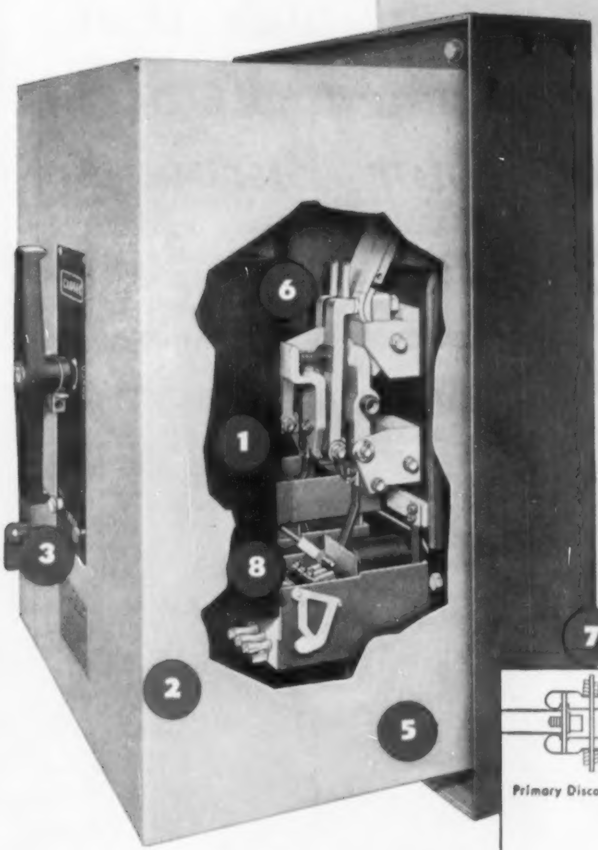
STOCKED COAST TO COAST
Standard Rockbestos A.V.C. construction (N.E.C. types AVA, AVB, etc.) are available for immediate shipment. Call or write nearest branch office.

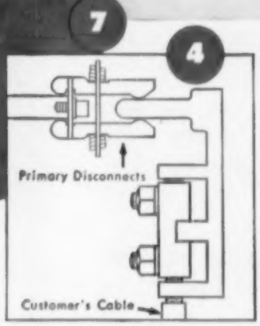
ROCKBESTOS PRODUCTS CORP.
NEW HAVEN 4, CONNECTICUT

NEW YORK CLEVELAND • DETROIT • CHICAGO • PITTSBURGH • ST. LOUIS • LOS ANGELES • NEW ORLEANS
OAKLAND, CALIFORNIA

ALLIS-CHALMERS
Individually Enclosed
Low Voltage Breakers

For service to 600 volts ac, 1600 amp continuous; 50,000 RMS amperes interrupting at 600 volts ac.





1. Dead front—Even with enclosure cover removed, breaker is entirely safe.

2. Accessible — Deep, removable front cover permits easy inspection and maintenance from both sides and front.

3. More safety — Interlock prevents removal of cover while breaker is in closed position.

4. Pull-out construction—Easy removal of breaker without disconnection of cables. Access to cable connections through entire front opening.

5. Weather-proof or dust-proof as well as standard, general purpose enclosures are available.

6. Long life contacts — Blow-on type action means high contact pressure — no bounce — less erosion.

7. Positive high pressure connection provided by compression springs on primary disconnects.

8. Accurate time-delay control provided by hermetically sealed, positive displacement trip device.

Get More Information — **Contact your nearby A-C office, or write Allis-Chalmers, Power Equipment Division, Milwaukee 1, Wisconsin, for Bulletins 18B8252 and 18B8283.**

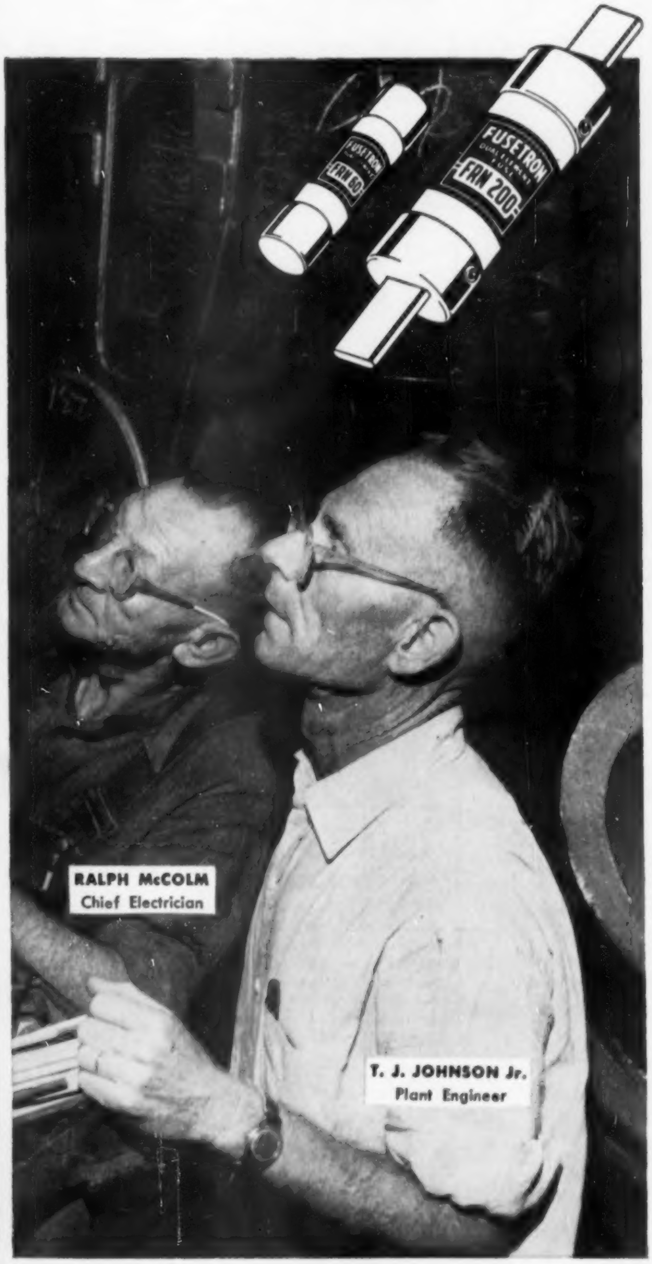
ALLIS-CHALMERS

A-4932

why Fusetron Fuses can protect motors against burnout

Fusetron fuses have a tremendous time-lag. This means, on normal installations, Fusetron fuses can be used in motor-running protection sizes — without opening on motor-starting current or other harmless overloads.

When so used, Fusetron fuses protect motors from any harmful excess of current caused by such things as single phasing, overloading, wrong voltage, being stalled, lack of oil, tight belt, worn bearings or anything that causes the motor to draw a dangerously excessive current.



Fusetron Fuses provide simplest way to prevent damage from single phasing

When single phasing occurs, the current in the remaining phase increases about 100%. (Theoretically 73%, but change in efficiency and power factor makes it about 100%).

This 100% overload on Fusetron fuses of motor-running protection size opens them and stops flow of current to the motor.

FUSETRON FUSES DO MORE THAN PROTECT MOTORS AGAINST BURNOUT

They provide 10 Point Protection

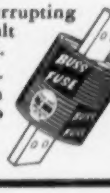
1. High interrupting capacity — protect against heaviest short-circuits. Have proven on tests to open safely on circuits set to deliver in excess of 100,000 amperes.
2. Protect against needless blows caused by excessive heating — lesser resistance results in cooler operation.
3. Protect against needless blows caused by harmless overloads.
4. Provide thermal protection — for panels and switches against damage from heating due to poor contact.
5. Protect against waste of space and money — permit use of proper size switches and panels.
6. Protect motors against burnout from overloads.
7. Give DOUBLE burnout protection to large motors — without extra cost.
8. Protect motors against burnout due to single phasing.
9. Make protection of small motors simple and inexpensive.
10. Protect coils, transformers and solenoids against burnout.

More information on Fusetron dual-element fuses is available. Write for bulletin FIS.

FOR LOADS ABOVE 600 AND UP TO 5000 AMPS. — USE BUSS Hi-Cap FUSES!

On 600 volts or less, they have interrupting capacity sufficient to handle any fault current regardless of system growth.

They can be coordinated with Fusetron fuses on feeder and branch circuits to limit fault outages to circuit of origin.



Write for bulletin HCS.

Play Safe! *Install FUSETRON dual-element Fuses and BUSS Hi-Cap Fuses throughout entire Electrical System!*

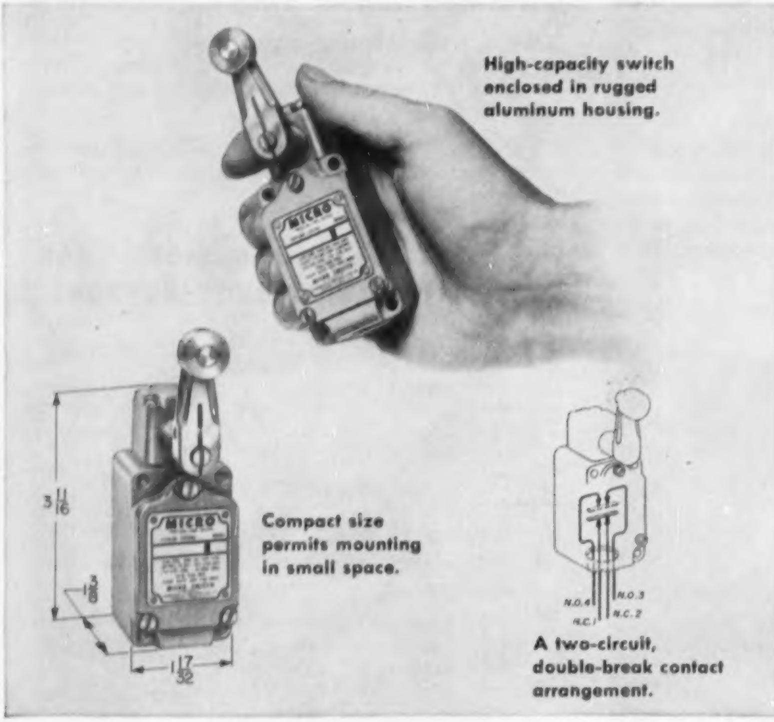
506

BUSSMANN MFG. CO. FUSETRON BUSS Div. of McGraw Electric Co.

University at Jefferson, St. Louis 7, Mo.

MICRO *precision switches*

...THEIR USE IS A PRINCIPLE OF GOOD DESIGN



High-capacity switch enclosed in rugged aluminum housing.

Compact size permits mounting in small space.

A two-circuit, double-break contact arrangement.

Here is a compact 2-circuit limit switch that meets a wide variety of plant applications

This MICRO precision switch is designed to meet every requirement for a compact 2-circuit switch for use as a limit, safety or interlock switch on complex production equipment.

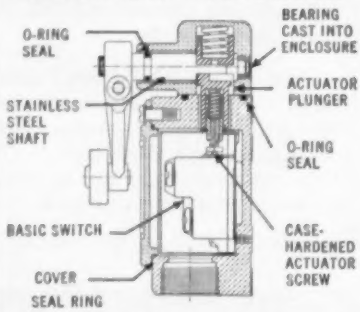
It has small size, extreme versatility, precision, reliability and ruggedness. All moving parts and the switching chamber are completely sealed, protected from wear or becoming fouled. Field adjustability permits its use in any type of application or location.

Two-circuit contact arrangement allows flexibility in circuit design. Reliability of the precision, snap-action unit assures accurate repeat operation throughout many millions of hard, fast actuations. Although small and compact in size, this switch is not only a precision instrument. It is designed and built to stand the most severe abuse.

The electrical rating is: 10 amperes 120, 240 or 480 volts a-c; ½ H.P. 115 volts a-c; 1 H.P. 230 volts a-c; .2 ampere 115 volts d-c; .1 ampere 230 volts d-c; .04 ampere 550 volts d-c. Pilot duty rating is: 600 volts a-c, max.

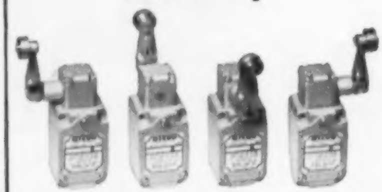
Like many other precision switches in the MICRO SWITCH line, this versatile 2-circuit switch is an ideal component for installation on present plant equipment. MICRO precision switches make production machinery safer, more automatic and more productive.

Seals Provide Maximum Protection



Sealing is provided by use of O-ring seals on the actuator shaft and between the actuator head and the housing. A synthetic rubber ring seal is provided for the cover. These seals provide maximum protection against entrance of dust, oil and other liquids. The switch meets NEMA specifications for an oil-tight pilot device.

Adjustable Head Assembly



The switch is easily mounted in almost any location. The user can remove the head and locate it in any of 4 positions (as illustrated).

Field Adjustable Actuator

The roller arm actuator is field adjustable through 360 degrees, positively locking in any position. Actuators are assembled to operate in either direction. They can also be converted to operate in one direction only, clockwise or counterclockwise

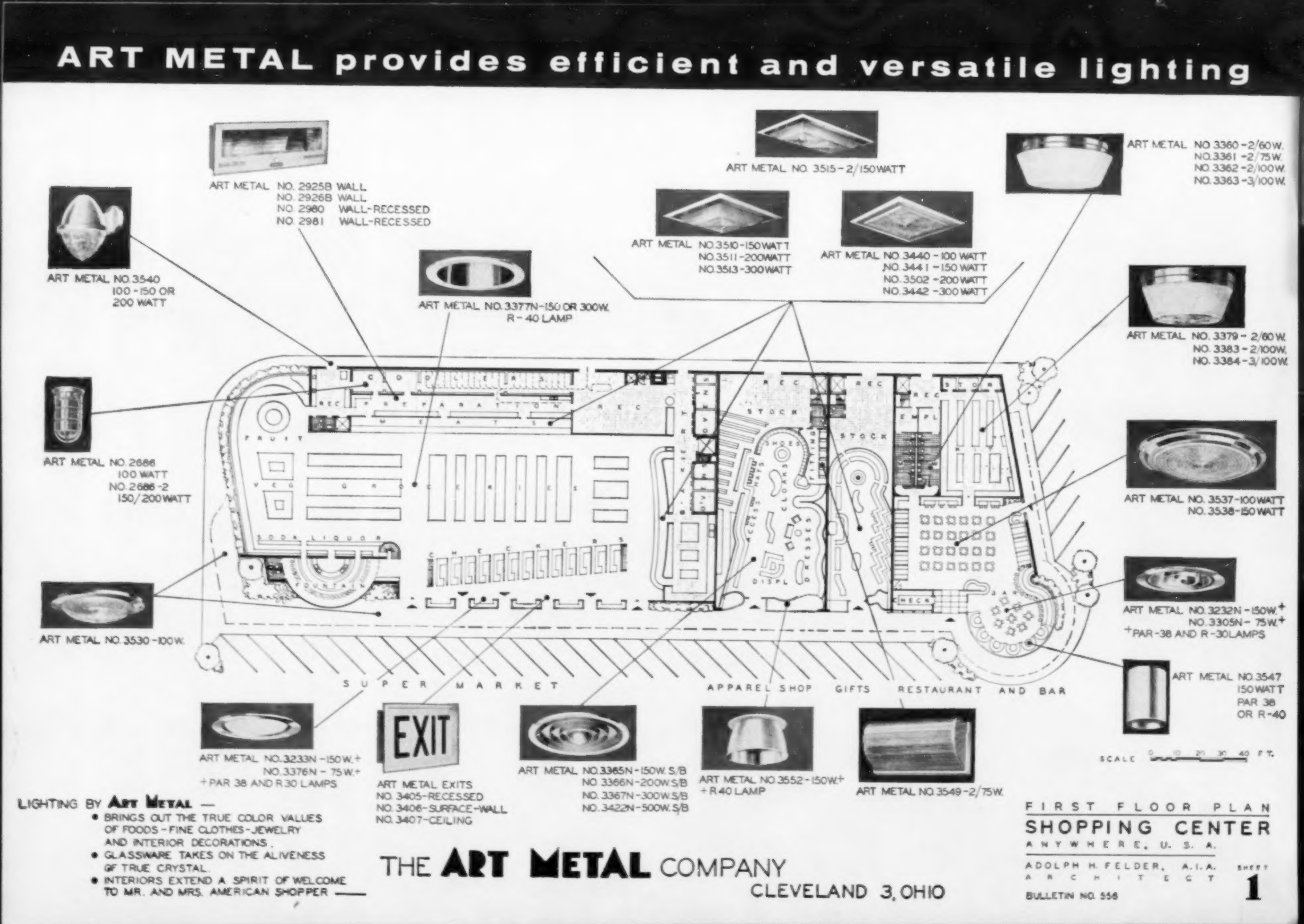
Send for new catalog 83 on industrial enclosed switches.

MICRO precision switches are sold by distributors in key cities everywhere. Look under "Switches, Electric" in the yellow pages of your phone book.

MICRO SWITCH

A DIVISION OF MINNEAPOLIS-HONEYWELL REGULATOR COMPANY

In Canada, Leaside, Toronto 17, Ontario • FREEPORT, ILLINOIS



ART METAL provides efficient and versatile lighting
ART METAL NO. 2925B WALL
NO. 2926B WALL
NO. 2980 WALL-RECESSED
NO. 2981 WALL-RECESSED
ART METAL NO. 3515-2/150WATT
ART METAL NO. 3360-2/60W.
NO. 3361-2/75W.
NO. 3362-2/100W.
NO. 3363-3/100W.
ART METAL NO.3540
100-150 OR
200 WATT
ART METAL NO.3510-150WATT
NO.3511-200WATT
NO.3513-300WATT
ART METAL NO. 3440-100 WATT
NO. 3441-150 WATT
NO. 3502-200 WATT
NO. 3442-300 WATT
ART METAL NO. 3377N-150 OR 300W.
R-40 LAMP
ART METAL NO. 3379-2/60W.
NO. 3383-2/100W.
NO. 3384-3/100W.
ART METAL NO. 2686
100 WATT
NO. 2686-2
150/200 WATT
ART METAL NO. 3537-100WATT
NO. 3538-150WATT
ART METAL NO. 3530-100W.
ART METAL NO. 3232N-150W.+
NO. 3305N-75W.+
+PAR-38 AND R-30LAMPS
ART METAL NO.3547
150WATT
PAR 38
OR R-40
SUPER MARKET
APPAREL SHOP
GIFTS
RESTAURANT AND BAR
ART METAL NO.3233N-150W.+
NO.3376N-75W.+
+PAR 38 AND R 30 LAMPS
EXIT
ART METAL EXITS
NO. 3405-RECESSED
NO. 3406-SURFACE-WALL
NO. 3407-CEILING
ART METAL NO.3365N-150W. S/B
NO 3366N-200W.S/B
NO. 3367N-300W.S/B
NO. 3422N-500W.S/B
ART METAL NO.3552-150W.+
+R40 LAMP
ART METAL NO.3549-2/75W.
SCALE 0 10 20 30 40 FT.
LIGHTING BY ART METAL —
• BRINGS OUT THE TRUE COLOR VALUES OF FOODS - FINE CLOTHES - JEWELRY AND INTERIOR DECORATIONS.
• GLASSWARE TAKES ON THE ALIVENESS OF TRUE CRYSTAL.
• INTERIORS EXTEND A SPIRIT OF WELCOME TO MR. AND MRS. AMERICAN SHOPPER —
THE ART METAL COMPANY
CLEVELAND 3, OHIO
FIRST FLOOR PLAN
SHOPPING CENTER
ANYWHERE, U. S. A.
ADOLPH H. FELDER, A.I.A.
ARCHITECT
SHEET
1
BULLETIN NO. 558

Circle rolls its own copper rod at Hicksville. Later this rod is shipped to the Maspeth plant for wire drawing to all sizes. Circle also sells hot rolled copper rod to other industrial users.

In addition to single conductor wire, Circle also produces stranded wire and cable. This high speed machine can assemble 12 wires to form concentrically stranded cable.

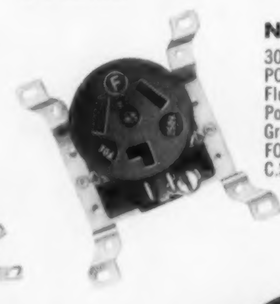
All of Circle's products are made to rigid quality standards. Here, rubber-insulated wire is tested in water under an electric charge. Any defect is immediately recorded.

From any angle... it pays to use a Circle F device!

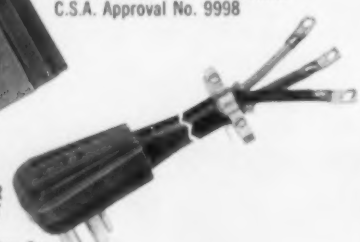
No matter what the problem or the product, if it's in the electrical field, we either have the device needed or our research department can tailor-make one for you.

And this is no idle boast. We proudly point to our fifty two years of complete service to the electrical industry with quality products at lowest prices and fast service.

NO. 3630
30 AMP. DRYER AND
POWER RECEPTACLE
Surface Mounting
Heavy Bakelite
Polarized with "L" Shaped
Grounding Slot
FOR DRYER AND POWER CORDS
C.S.A. Approval No. 9998



NO. 3631
30 AMP. DRYER AND
POWER RECEPTACLE
Flush Mounting
Polarized with "L" Shaped
Grounding Slot
FOR DRYER AND POWER CORDS
C.S.A. Approval No. 9998



NO. 3530
30 AMP. 3-WIRE DRYER
AND POWER CORD SET
All Rubber 32" Long
One Piece Molded Rubber Cap
Includes Cable Clamp

NO. 2573-L
3-WIRE BAKELITE
GROUNDING ADAPTER
Polarized slots and
Polarized blades plus
"U" shaped grounding slot
C.S.A. Approval No. 1293

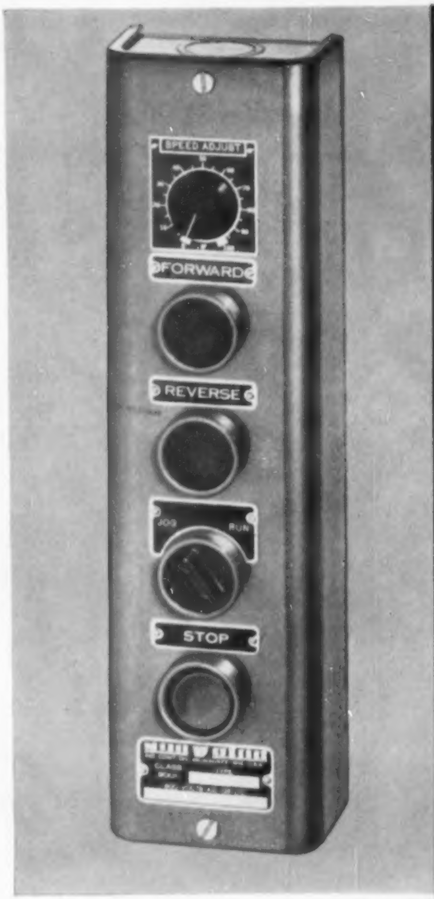
50 YEARS

Circle F Mfg. Co.

TRENTON 4, N. J.

SAVING YOU MORE SINCE 1904

Eastern Insulated Wire Corp. Wallingford, Conn. A subsidiary



The "Unseen Hand" at the Controls . . .

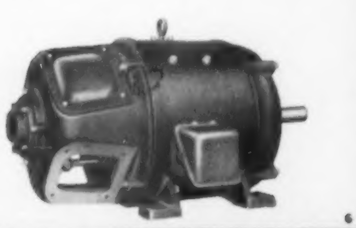
AUTOMATICALLY SENSITIVE

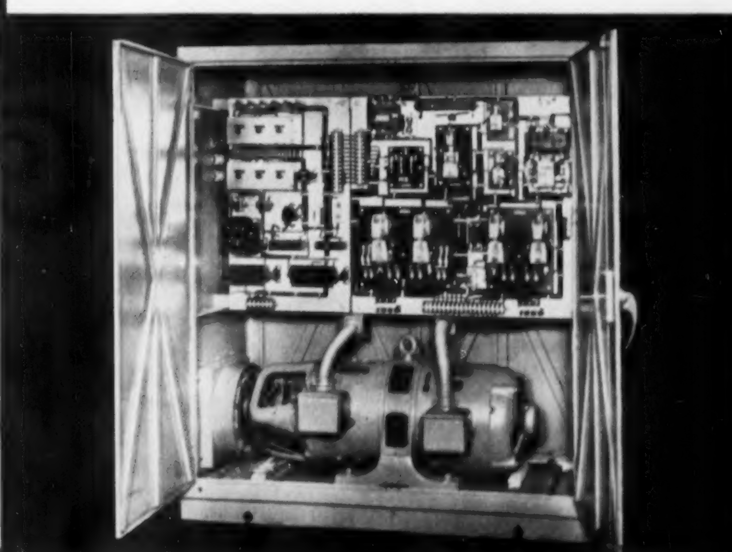
Performance-Rated©

Century SELECTIVE SPEED DRIVE

More accurately than the most experienced operator, Performance-Rated Century Selective Speed Drives *automatically* adjust motor speed to meet operating requirements. Speed changes are integrated with varying pressure, temperature, viscosity or size of the material being worked. You can also use Century Selective Speed Drives for starts, stops and jogs—forward or reverse—as required.

For full information and assistance on any motor drive application, AC or DC, call your nearest Century Sales Office . . . or write us direct.





Performance-Rated©
1/8 to 400 H. P.

CENTURY ELECTRIC COMPANY

1806 Pine St., St. Louis 3, Mo. • *Offices and Stock Points in Principal Cities*

A DEPENDABLE COMBINATION

Westinghouse Bus Duct—made with Kaiser Aluminum Bus Bar—offers many advantages that result in better bus duct systems. Among these advantages are:

Application flexibility—Westinghouse Bus Duct using aluminum bar is normally applicable to all installations where duct using copper bar is currently used. There are distinct advantages to consider when comparing the use of aluminum with copper in any particular application.

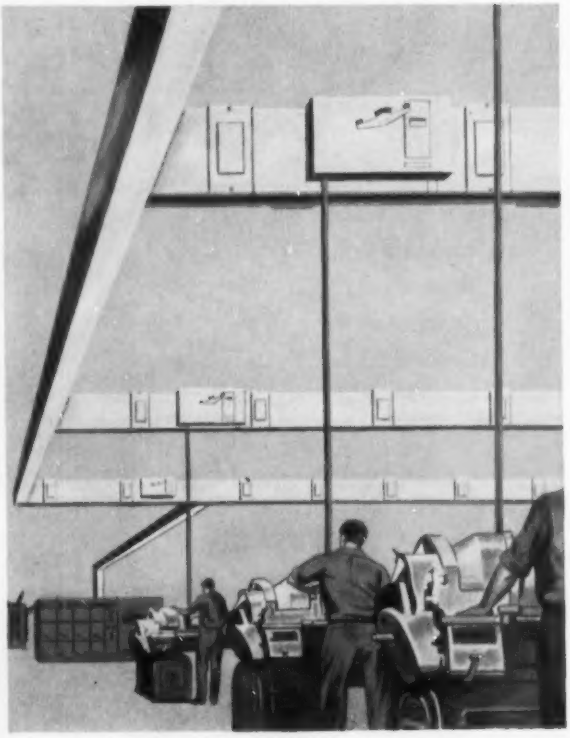
Up to one-third less weight—the cross-sectional area of aluminum bus bar for comparable current capacity is only slightly greater than that of copper bus bar. But, aluminum is a little less than one-third the weight of copper by volume. Thus, a 10-foot section of bus duct using aluminum bar is approximately 30% lighter than a 10-foot section of bus duct using copper bar.

Easier handling—Lighter weight and easier handling go hand in hand. Every step of the way from transporting to installing, personnel find the lighter weight of aluminum a distinct advantage.

Lower first cost—At present approximately 10% saving over equivalent copper duct can be realized. Increased use resulting in lower manufacturing costs will increase this saving still further.

Lower installation cost—This is primarily due to being able to handle bus duct using aluminum bar with greater ease. Less time is required to get the duct in place.

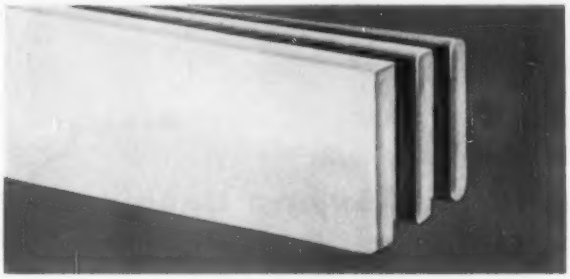
Lighter floor loading—This is another benefit of lighter weight of particular value when bus duct is used as part of a modernization program, especially when it comes to installing duct as vertical risers in commercial buildings. Aluminum bus duct is the answer.



In addition, Westinghouse has built in the same assurance of low resistance joints that are available in duct fabricated with copper bar. Each bar is electrolytically silver plated over its entire length to provide the same consistent low contact electrical resistance which

KAISER WIRE

FOR BETTER BUS DUCT SYSTEMS



is stable over long periods of time under varying operating conditions. In performance it is equivalent in every respect to copper bus duct and meets the same NEHA & U/L standards.

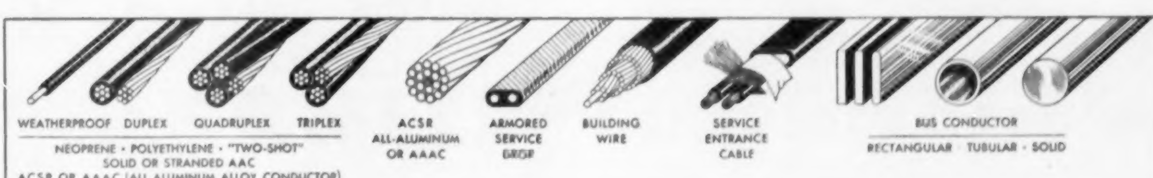
Detailed information on Westinghouse Aluminum Bus Duct can be obtained by writing to Westinghouse Electric Corporation, 3 Gateway Center P.O. Box 868, Pittsburgh 30, Pennsylvania.

• Aluminum's unique combination of useful properties make Kaiser Aluminum Bus Conductor ideal for use in industrial plants, commercial buildings, central stations and substations. Among its advantages are high conductivity, light weight, corrosion resistance, workability, strength, availability and economy.

To assist manufacturers, utilities, architects and engineers in the conversion to aluminum bus, Kaiser Aluminum makes available a large range of shapes, alloys, and sizes of aluminum bus conductor—including rectangular, tubular, and solid round bus. Ask for free booklet "Kaiser Aluminum Bus Conductors"—containing valuable information on types and advantages, availability, electrical properties, physical properties, bending, corrosion resistance, joining, and silver plating.

Kaiser Aluminum & Chemical Sales, Inc. *General Sales Office*, Palmolive Bldg., Chicago 11, Illinois; *Executive Office*, Kaiser Bldg., Oakland 12, California.

Kaiser Aluminum



LITECONTROL makes Eyeing and Buying Easier in this Drug Store installation

This drug store (part of a large shopping center) is designed to take heavy traffic and the lighting in turn is designed to focus the traffic's attention on the merchandise with maximum eye appeal.

Litecontrol's new series 6000 fixtures which are approximately two feet by four feet were used. This size and type fixture provides a large area of low brightness and transmits a lot of light without specular glare or harmful shadows. Note the evenness of illumination. The fixtures shown were furnished with Albalite #66 glass, but are also available with Plexiglas dish diffusers.

Relamping and cleaning are easy. A light touch on the Trigger Catches opens fixture doors, and an easy push into place closes them securely. This type fixture is also available for Grid type ceilings, and for surface mounting, both two feet by four feet and two feet by two feet. Also comes with two, three or four lamps.

If you want to play up merchandise and play down glare — put it up to Litecontrol. Yes, and you'll find there's a *standard* Litecontrol fixture that will do a quality lighting job for every type of public building. May we help *you?*

INSTALLATION: Bause Super Drug Store, Allentown, Penna.

ARCHITECT-ENGINEER: Supowitz & Demchick, Philadelphia, Penna.

ELECTRICAL CONTRACTOR: The Howard P. Foley Co., Allentown, Penna.

DISTRIBUTOR: Graybar Electric Co., Inc., Allentown, Penna.

FIXTURES: Litecontrol No. 6034RS-66 3 Lamp 40 Watt Rapid Start, recessed fixtures with Corning Albalite #66 ribbed diffusing glass. No. 6000-27 Plaster Frames also furnished.

INTENSITY: Approximately 55 footcandles average in service. (Date of installation, December, 1954).

LC

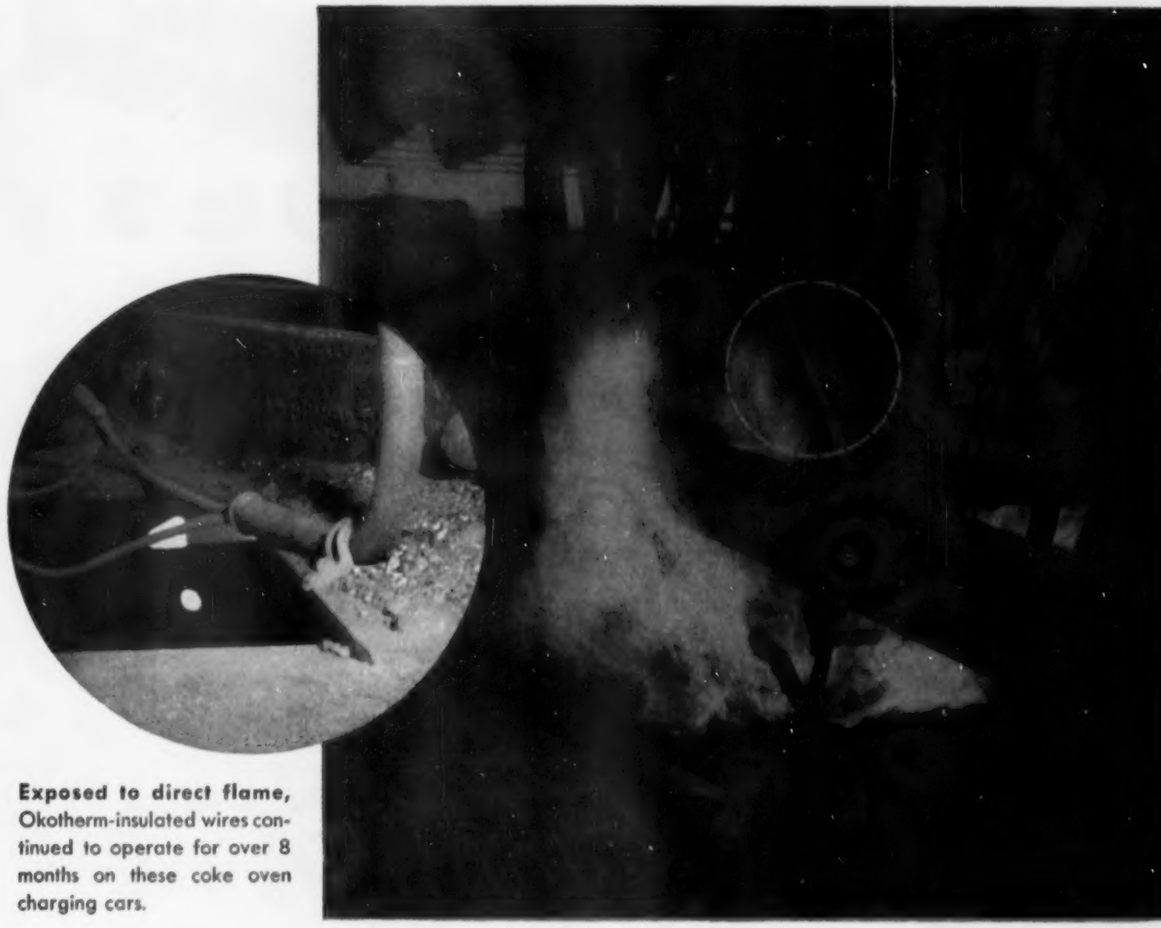
LITECONTROL
Fixtures

KEEP UPKEEP DOWN

LITECONTROL CORPORATION

36 PLEASANT STREET, WATERTOWN 72, MASSACHUSETTS

DESIGNERS, ENGINEERS AND MANUFACTURERS OF FLUORESCENT LIGHTING EQUIPMENT DISTRIBUTED ONLY THROUGH ACCREDITED WHOLESALERS



Exposed to direct flame, Okotherm-insulated wires continued to operate for over 8 months on these coke oven charging cars.

Okotherm-Insulated Wires lasted 8 months here

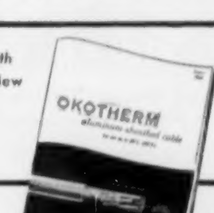
Until recently, one of the nation's largest commercial coke producers in the southeast had to replace at least one cable leading to the vibrators on its coke oven charging cars *"every shift, three shifts a day, thirty days a month."*

These replacements were necessary because the cables had to pass through flames toward the end of each charging operation. The company reported that this replacement cost them an average of $247.50 a month.

Eight months ago, they installed Okotherm-insulated wiring on the vibrators and lights of these cars. Since that time, no replacements have been required. The total wire and installation cost was less than $200. The "per month cost" already averages less than $25.00.

If you have a high ambient temperature cable problem, it will pay you to investigate Okotherm-insulated cables. Suitable for operation up to 200C, Okotherm-insulated cables are moisture- and ozone-proof and have high dielectric strength. Single and multiple-conductor power and control cable constructions are available.

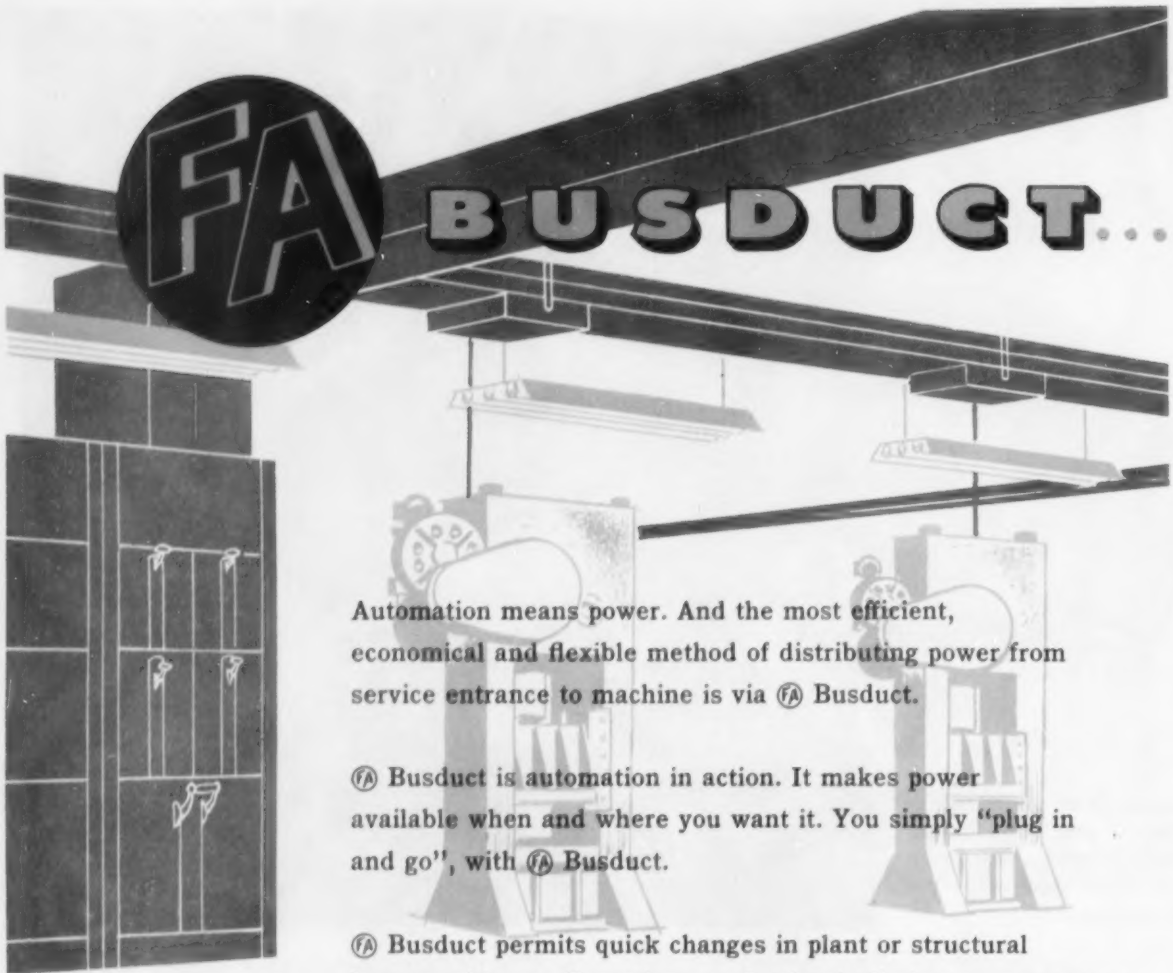
NEW— Okotherm-insulated cable *with aluminum sheath.* Eliminates conduit. New Bulletin EC-1088 gives all details. Write for it today to The Okonite Company, Passaic, N. J.



OKONITE PASSAIC, N.J.

OKONITE OKONITE SINCE 1878 ***insulated cables***

2953



Automation means power. And the most efficient, economical and flexible method of distributing power from service entrance to machine is via Ⓕ Busduct.

Ⓕ Busduct is automation in action. It makes power available when and where you want it. You simply "plug in and go", with Ⓕ Busduct.

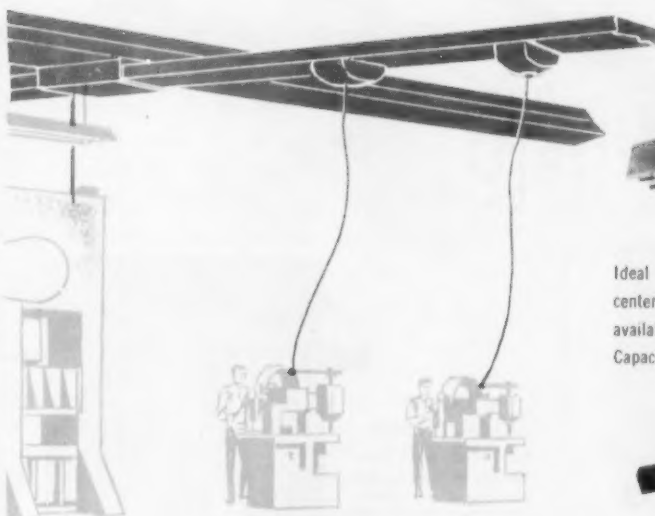
Ⓕ Busduct permits quick changes in plant or structural layout without disrupting production, eliminates temporary connections and long lead-ins, cuts maintenance costs and affords other savings by reducing power loss caused by voltage drop to a minimum. Too, it is 100 percent salvageable.

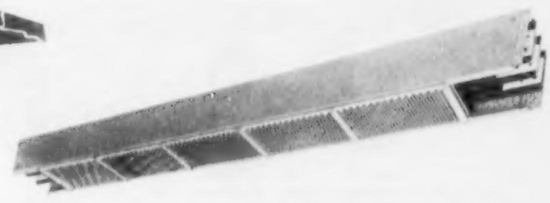
Ⓕ Busduct is approved by the Underwriters' Laboratories, Inc., for label service. It is made in standard lengths, and can be used to fit almost any electrical requirement. Sections can be run horizontal, or vertical, on floor level or overhead, through walls and tunnels, with raintite or dustite construction for special installation.

For the maximum in efficiency, economy and flexibility of plant operations, install Ⓕ Busduct, the modern system of power distribution.

For further information about Ⓕ Busduct consult your nearest Ⓕ representative listed in Sweet's or write for Bulletin.

the backbone of AUTOMATION





FEEDER BUSDUCT

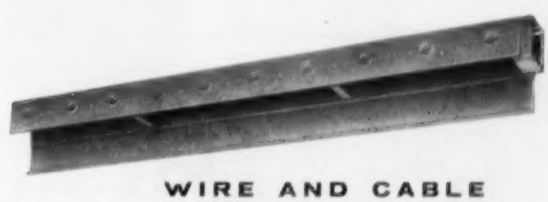
Ideal for conducting heavy current from service entrance to distribution center. Available in single bar and Hi-Efficiency types. Hi-Efficiency duct is available in three types-open, protected ventilated and totally enclosed. Capacities 600 to 4000 amps, 600 volts and less.

POWERPLUGIN MIDGET SIZE

Provides "plug in and go" power for all small installations. Made in five and ten foot sections with plugin outlet every 12 inches. Ratings 100 amperes, 250 volts feeder capacity. Also available in 2, 3 and 4 conductor, solid neutral types.

POWERPLUGIN

Provides plug-in outlet every foot of the way (Standard with outlets on 10 inch centers on one side. Available also with outlets on 20 inch centers on both sides.) Excellent for connection of machines, closer grouping of equipment etc. Ratings 225 to 1500 amps, 600 volts AC and less, with Klampswitch-fuz, Shutlbrak and Circuit Breaker plugin devices for 200 amperes or less..



WIRE AND CABLE DUCT

Provides complete distribution system for electric lights, heat or power and a signal system such as permitted under the National Electric Code Rules. Ideal for bringing a number of wires into a limited space. Duct is 2½" x 2½", 4" x 4" and 6" x 6" in size and is available in 1, 2, 5 and 10 foot sections with elbows, end enclosures, tees, etc. Special types available.

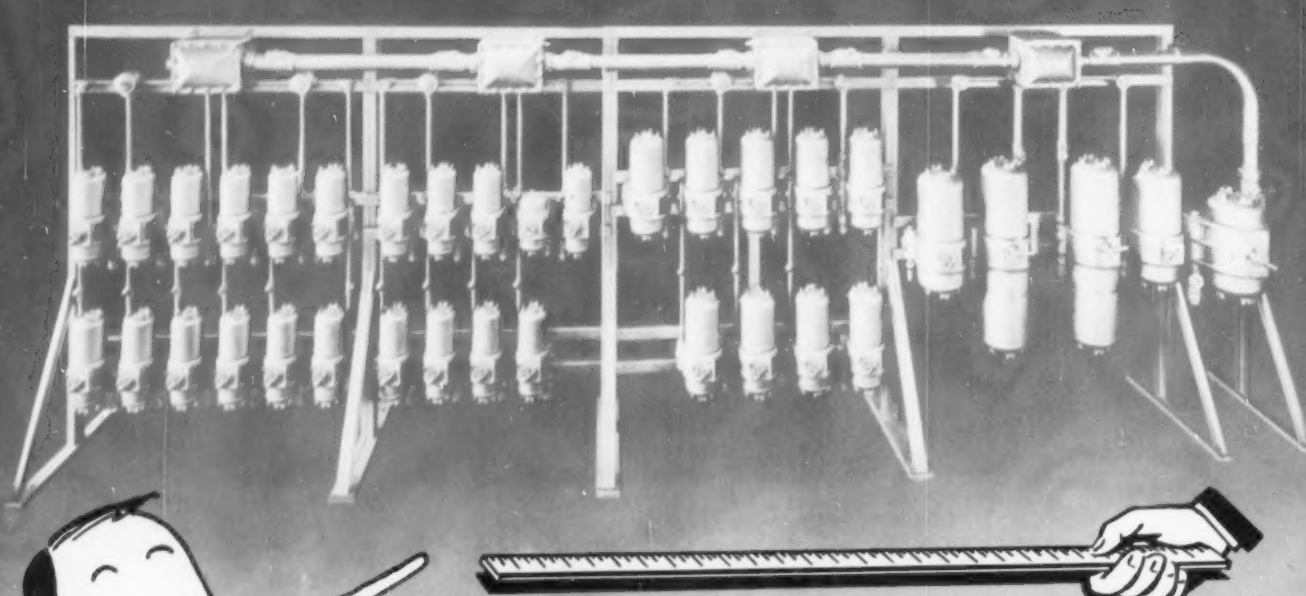
FA

Frank Adam Electric Co.

Phone JEfferson 3-6550
BOX 357, MAIN P. O. • ST. LOUIS 3, MO.

makers of:
busduct • panelboards • switchboards
service equipment • safety switches
load centers • Quikheter

Crouse-Hinds Explosion-Proof and Dust-Tight Motor Controls



World's Widest Line

...offers exclusive compactness to conserve costly space!

Easiest Installation Known!

An electrician and only one helper can install the largest EPC combination starter and breaker. For example, the heaviest component in the 100 H.P. size weighs but 85 lbs. Components are few — just four: center body section, starter and breaker assembly, and two covers. The high-domed cover removes to expose starter and breaker assembly on all sides, thus providing complete wiring ease.

A given area will hold MORE Crouse-Hinds motor controls than any other make

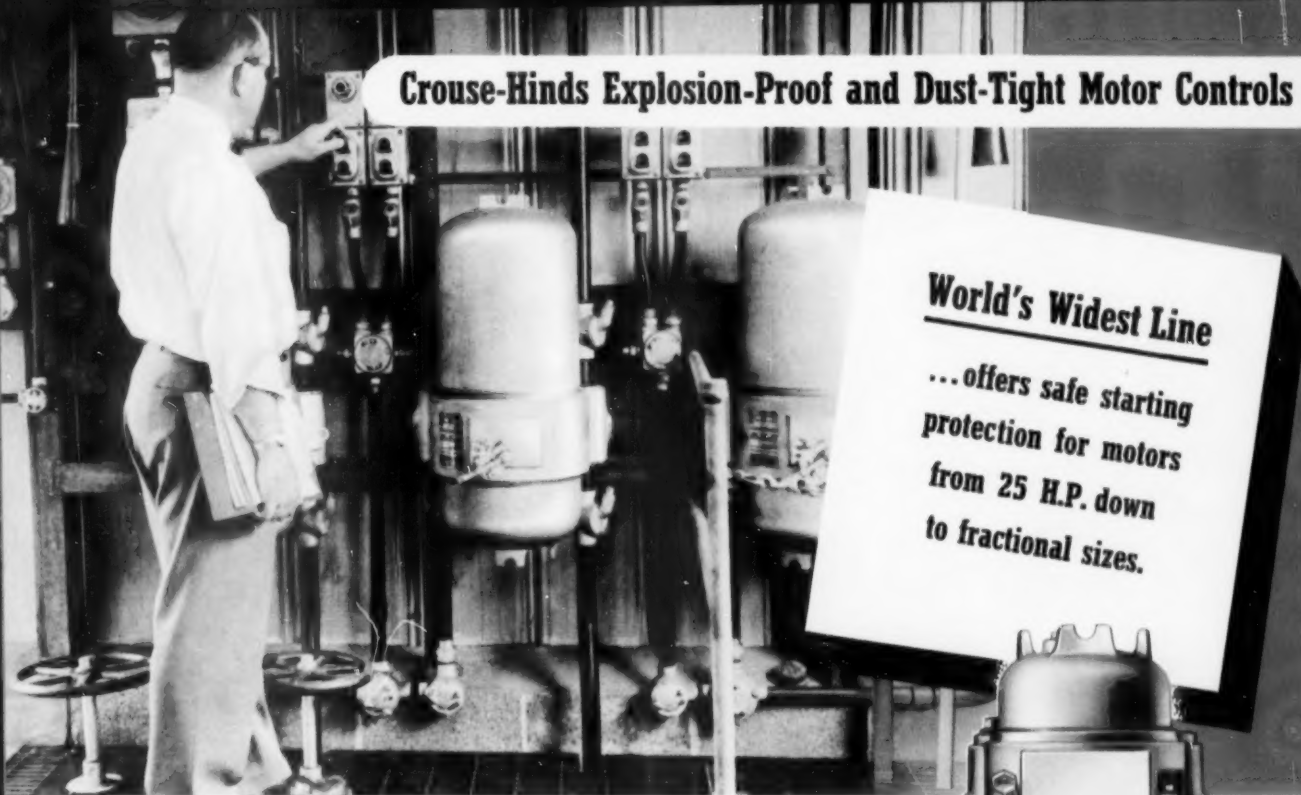
In the typical installation above, there are 33 Crouse-Hinds Type EPC combination motor starters and circuit breakers . . . plus space for 2 more . . . plus 2 circuit breakers . . . *all in 28′ x 10′ of space!* Conventional single-tiered installation would have required a rack 20′ longer, and 4 more junction boxes. Additional money was saved on the construction of steel mounting racks.

● A postcard will bring our Condulet catalog to you by return mail.

CROUSE-HINDS COMPANY

SYRACUSE 1, N.Y.

Crouse-Hinds Explosion-Proof and Dust-Tight Motor Controls



World's Widest Line

...offers safe starting protection for motors from 25 H.P. down to fractional sizes.

EPC Line Starter Condulets

For across-the-line magnetic motor starting of polyphase A.C. induction motors. Provide undervoltage and thermal time limit overload protection. Available air-break or oil-immersed; one or two speed and reversing. Compact circular design is lighter, easier to install. Threaded joint covers provide maximum protection. Size 0 through 5. Up to 550V, A.C.

National Electrical Code - Class I, Group D; Class II, Groups E, F & G; and Class III.

GUB Line Starter Condulets

For across-the-line magnetic motor starting of polyphase A.C. induction motors. Provide undervoltage and thermal time limit overload protection. Threaded covers for maximum protection. Furnished with local or for remote push button control. Sizes 0, 1 and 2. Up to 550 V., A.C.

National Electrical Code - Class I, Group D; Class II, Groups E, F, & G; and Class III.

FLF Manual Line Starter Condulets

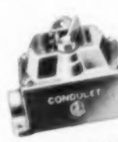
For across-the-line manual motor starting of direct current or single and polyphase A.C. motors. Provide thermal time limit over-load protection. Through-feed hubs, or both at bottom. Threaded covers set at an angle provide ease of wiring. Lever may be padlocked in "on" or "off" position. Available with a broad variety of well-known starters. Sizes 0 and 1. Up to 550V, A.C.

National Electrical Code - Class I, Group D; Class II, Groups E, F, & G; and Class III.

There's a Wide Range of Fractional HP Controls

National Electrical Code - Class I, Groups C & D; Class II, Groups E, F, & G; and Class III.

OFC Manual Motor Starting Switch Condulets, up to 1 H.P., 230 V.

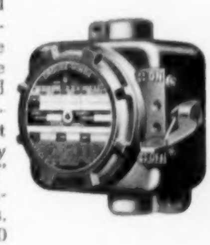


EFD Manual Motor Starting Switch Condulets, Single or 2-gang up to 2 H.P., 600 V., A.C.

FSPC Motor Sentinel Condulets, up to 1 H.P., 230 V.

EFS Manual Motor Starting Switch Condulets, Single or 2-gang, up to 1 H.P., 230 V.

GUSC Manual Line Starter Condulets



For across-the-line manual motor starting of direct current or single and polyphase A.C. motors. They provide thermal time limit overload protection, but do not provide undervoltage or short circuit protection. Lever may be padlocked in either "on" or "off" positions. Through-feed hubs, threaded covers. Sizes 00, 0 and 1, up to 460 V., A.C.

National Electrical Code - Class I, Groups C and D; Class II, Groups E, F, & G; and Class III.

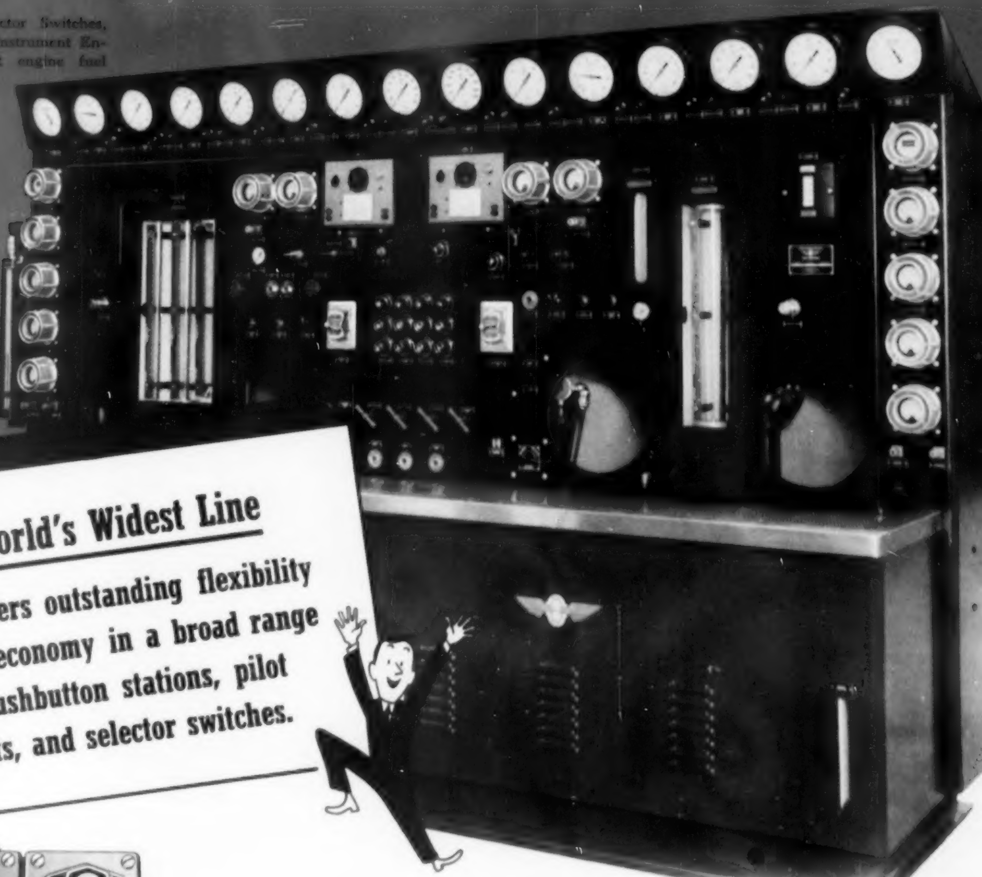
✓ *Send* **for our Condulet catalog.**

CROUSE-HINDS COMPANY

SYRACUSE 1, N. Y.

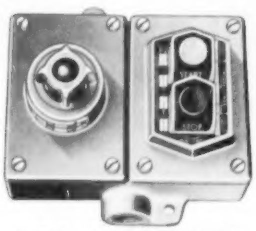
Crouse-Hinds Explosion-Proof and Dust-Tight Motor Controls

Crouse-Hinds Selector Switches, Pilot Lights, and Instrument Enclosures on a jet engine fuel testing panelboard.



World's Widest Line

...offers outstanding flexibility and economy in a broad range of pushbutton stations, pilot lights, and selector switches.



EFS Combination Pushbutton Station and Pilot Light Condulet

Crouse-Hinds Condulet pilot lights and switches provide visual indication of process stages, and instant control of processing or manufacturing equipment. The correct selection of these accessories will provide maximum safety in any hazardous area, indoors or out.

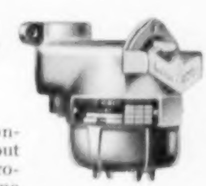
EFS and EFD Condulets

Included in these series are pushbutton station, pilot light and selector switch Condulets — singly, or in any combination in gangs. Special features available: pushbutton or side rocker locking devices; top or side operated tumbler switches with operating key; devices for remote control of pushbuttons.

National Electrical Code: Class I, Groups C & D; Class II, Groups E, F, & G; and Class III.

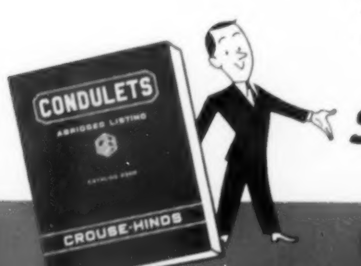
EFD Pushbutton Station and Pilot Light Condulet (factory sealed—no external seals required)

OFC Pushbutton Stations and Selector Switches for Oil Immersed or Air Break Devices



OFC Condulets are explosion-proof without the use of oil, but oil may be used to prevent corrosion simply by filling the dome shaped cover which is threaded to the bottom of the body. Also included in the OFC Series are Time Delay Pushbutton Condulets for automatically restarting motors stopped by momentary power fluctuation or failure.

National Electrical Code: Class I, Group D; Class II, Groups E, F and G; and Class III.

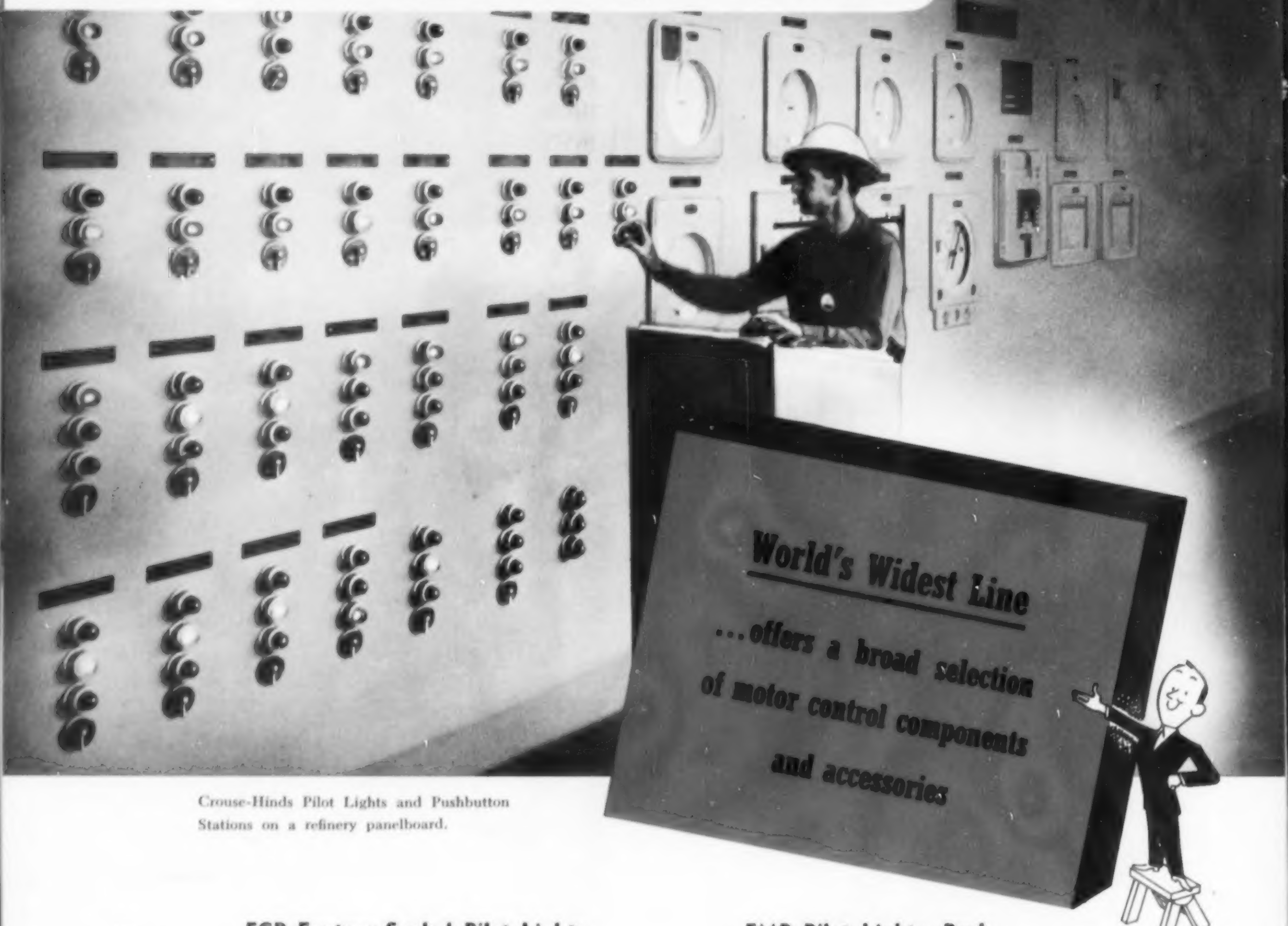


Send for our Condulet Catalog today!

CROUSE-HINDS COMPANY

SYRACUSE 1, N. Y.

Crouse-Hinds Explosion-Proof and Dust-Tight Motor Controls



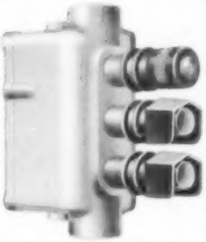
Crouse-Hinds Pilot Lights and Pushbutton Stations on a refinery panelboard.

Type EGP Three-Gang with One Push button Station and Two Pilot Lights Mounted on Steel Panel

EGP Factory Sealed Pilot Lights, Pushbutton Stations and Combinations for Panel Mounting

EGP pushbutton stations, pilot light and selector switch Condulets may be used singly or in a wide variety of combinations. Construction provides for flush mounting of pilot lights, pushbuttons and switch handles on the panel face. Condulet bodies for wiring and conduit connections are at the rear of the board.

National Electrical Code: Class I, Groups C & D; Class II, Groups E, F, & G; and Class III.



EMP Three Gang with Two Push button Stations and One Pilot Light

EMP Pilot Lights, Push Button Stations, Selector Switches and Combinations for Panel Mounting

EMP Condulets are very compact, requiring an absolute minimum of panel space consistent with thorough explosion-proof protection. For this reason they are ideally suited for flow chart panels. Pilot lights, pushbuttons and switch handles mount flush with panel front as in EGP Condulets at left. Large covers give maximum access to interior.

National Electrical Code: Class I, Groups C & D; Class II, Groups E, F, & G; and Class III.

Only a fraction of Crouse-Hinds explosion-proof, dust-tight motor controls has been shown here. The accessory equipment necessary to make a *complete* motor control installation – junctions, seals, unions, etc. – is described in detail in the Condulet catalog. Send for a copy. For help on an explosion-proofing problem, see a Crouse-Hinds distributor, or call the nearest Crouse-Hinds office listed below.

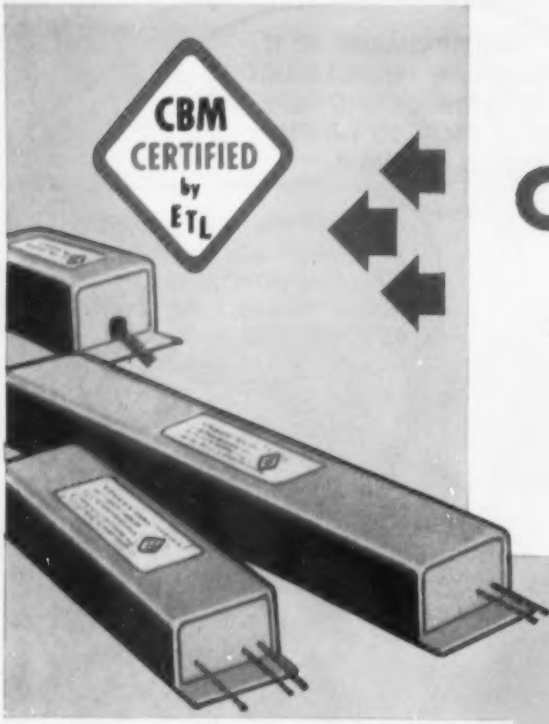
A NATIONWIDE DISTRIBUTION exclusively through ELECTRICAL DISTRIBUTORS

CROUSE-HINDS COMPANY

Main Office and Factory: Syracuse, N. Y.
Crouse-Hinds Company of Canada, Ltd.: Toronto, Ont.

OFFICES: Birmingham Boston Buffalo Chicago Cincinnati Cleveland Dallas Denver Detroit Houston Indianapolis Kansas City Los Angeles Milwaukee New Orleans New York Philadelphia Pittsburgh Portland, Ore. St. Louis St. Paul San Francisco Seattle Tulsa Washington RESIDENT REPRESENTATIVES: Albany Atlanta Baltimore Baton Rouge Charlotte Chattanooga Corpus Christi Jacksonville Reading, Pa. Richmond, Va. Shreveport

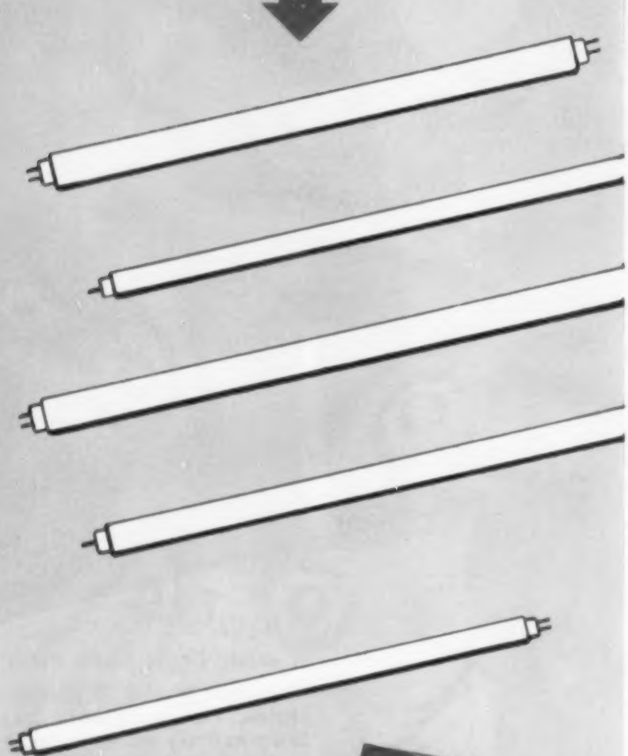
CONDULETS — FLOODLIGHTS — TRAFFIC SIGNALS — AIRPORT LIGHTING



CERTIFIED CBM BALLASTS

...give you more economical Fluorescent Lighting

because they are "Tailored to the Tube"



Every type and size of fluorescent tube has its own specific electrical requirements. Thus, to get ideal performance and lighting economy, it is essential that the ballasts provide precisely the electrical needs of the tubes they operate.

CERTIFIED CBM BALLASTS are "Tailored to the Tube." Built to exacting specifications, then tested and checked by ETL, an independent agency, CERTIFIED CBM BALLASTS are a dependable assurance of both satisfactory and economical fluorescent lighting.

Certified CBM Ballasts

PROVIDE:

- **LONG BALLAST LIFE**
- **FULL LIGHT OUTPUT**
- **LONG LAMP LIFE**
- **TROUBLE-FREE OPERATION**

all of which contribute to easier maintenance and fluorescent lighting economy.

Eight of the country's leading manufacturers of ballasts make CERTIFIED CBM BALLASTS. Participation in CBM is open to any manufacturer who wishes to qualify.

Send for free booklet, "Why It Pays to Use CERTIFIED CBM BALLASTS in Fluorescent Lighting Fixtures."

CERTIFIED BALLAST MANUFACTURERS

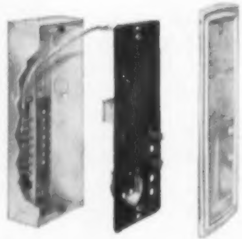
2116 KEITH BLDG., CLEVELAND 15, OHIO

NEW... most beautiful Apartment Telephones ever made!

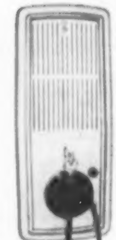
- Equipped with cordless loudspeaker or watchcase receiver—your choice
- Modern, slim, streamlined design
- Aluminum face plate with beautiful anodized finish in brushed gold or silver
- Plug-and-receptacle installation
- Easiest telephone in the world to install and maintain
- Excellent voice reproduction
- Competitive price
- Pleasant-sounding audible signal
- Flush, semi-flush or surface wall mounting

Auth vestibule and lobby telephones also have been re-designed and are the last word in appearance and efficiency. Get complete facts today.

Apartment and vestibule telephones illustrated are cordless loudspeaking type. Also available are apartment telephones with watchcase receiver as indicated.



Exploded view of cordless loudspeaking telephone



Watchcase receiver type

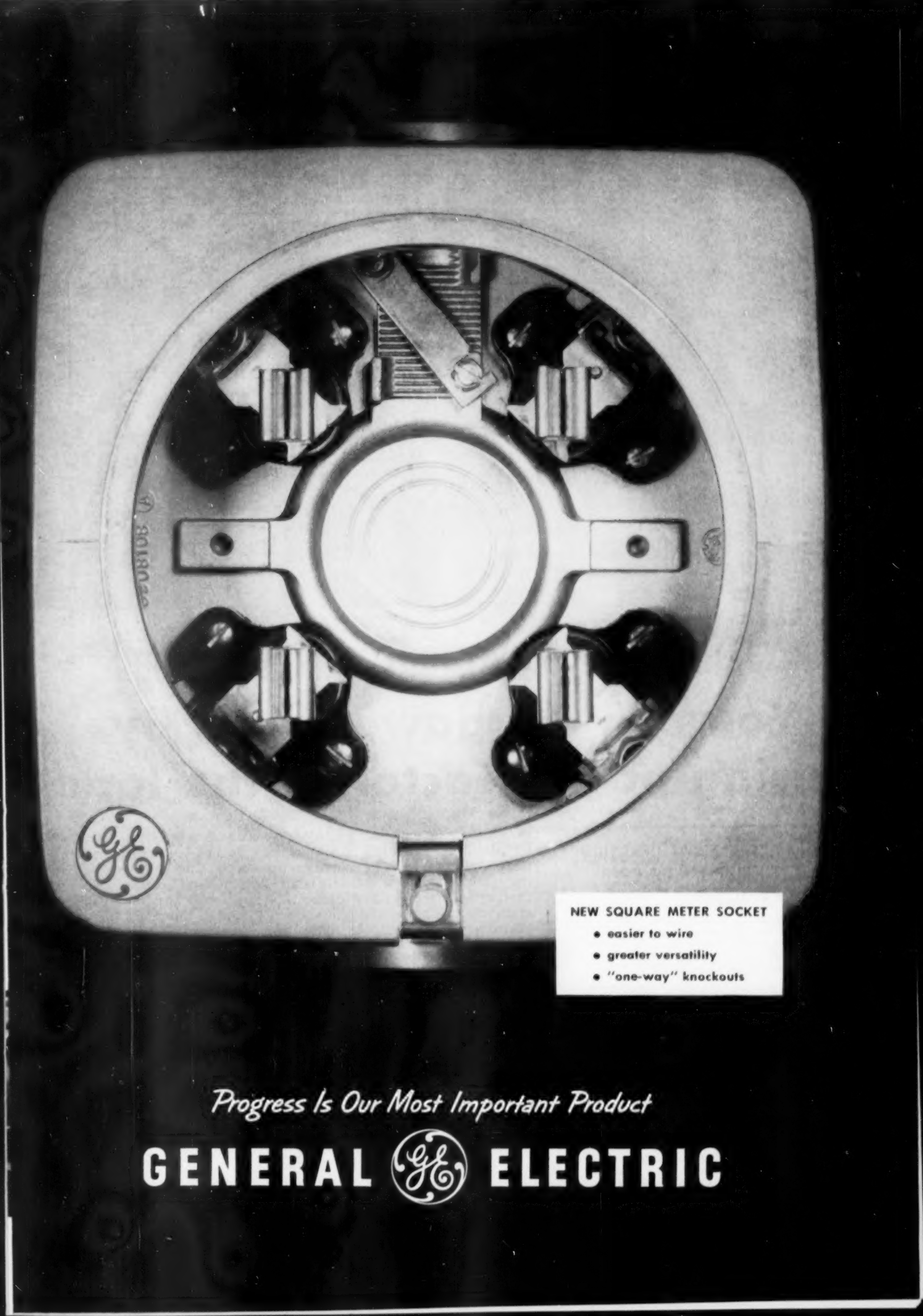
Auth

SINCE 1892

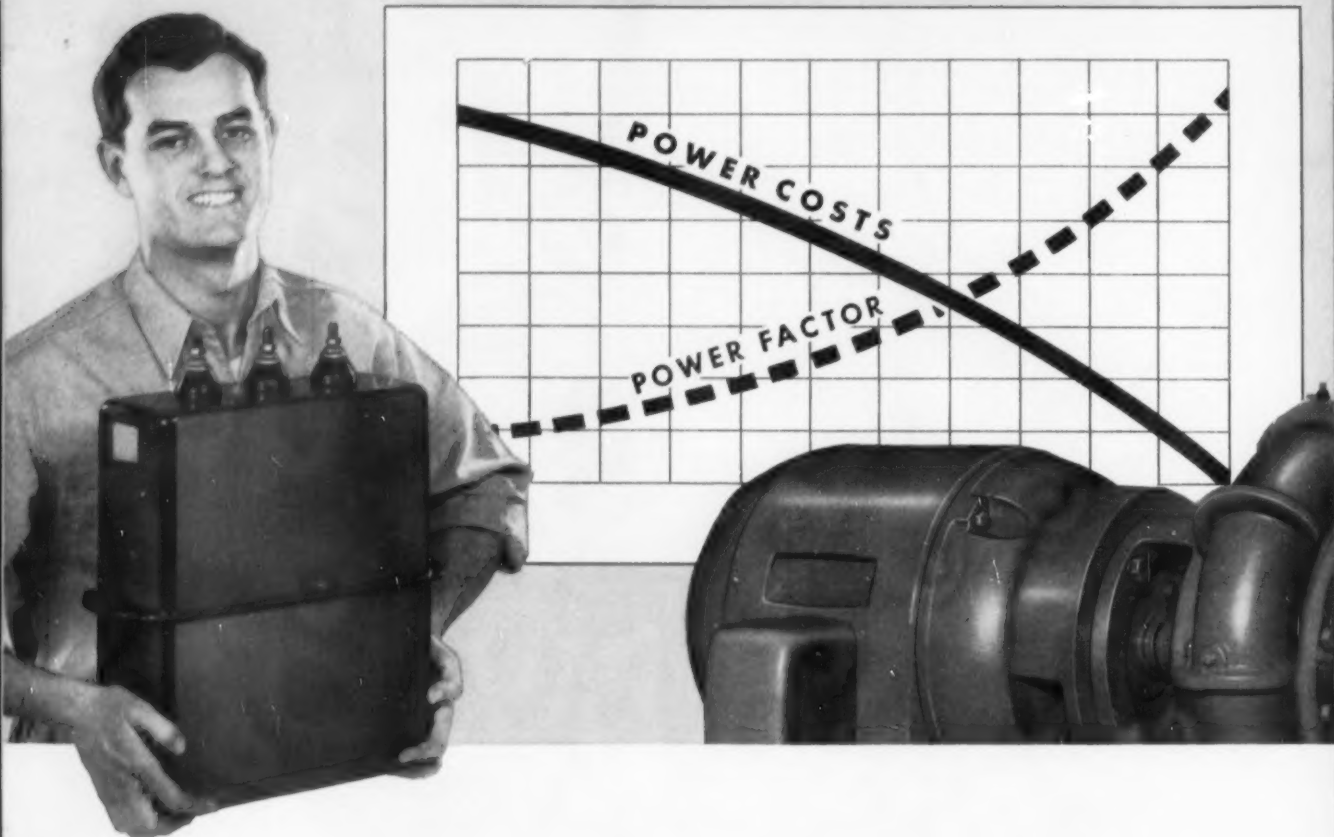
ELECTRICAL SIGNALING, TIME AND COMMUNICATION SYSTEMS FOR HOSPITALS, SCHOOLS, HOUSING, INDUSTRY AND SHIPS

Auth Electric Company, Inc.

LONG ISLAND CITY 1, NEW YORK


NEW SQUARE METER SOCKET
• easier to wire
• greater versatility
• "one-way" knockouts
Progress Is Our Most Important Product
GENERAL ELECTRIC

WITH GENERAL ELECTRIC CAPACITORS



You can cut power costs by raising power factor at the load

✓ CHECK THESE QUESTIONS TO FIND IF YOU NEED CAPACITORS:

- Do you use induction motors, welders, induction heaters or other inductive devices that may reduce your power factor below 95%? ☐
- Does your power contract include a power-factor penalty or KVA demand charge because your power factor is low? ☐
- Is low power factor overloading your electric system, cutting machine output or blocking increased production? ☐
- Do you suffer from low or fluctuating voltage because of heavy kilovar demands? ☐

If the answer is "yes" to any of these questions, G-E capacitors may effect important improvements in your plant operation as well as substantial savings on your power bills.

Poor power factor costs you money . . . money that can be saved by installing economical G-E capacitors. In almost every plant using electric motors, welders, induction heaters or other inductive electric equipment, poor power factor is an expensive, unwanted guest. It's the basis for the penalty clause that appears in the power bills of many electric power companies. And it's often the reason for overloaded power circuits, poor voltage and other plant electrical troubles.

General Electric capacitors supply magnetizing current (or kilovars) required by motors and other inductive equipment—right in your own plant. They relieve power circuits of the added burden of carrying this unproductive current. They can reduce your power bills. Once installed, they go on saving for you year after year.

Sounds too good to be true? It isn't! Many industrial plants find that power savings from G-E capacitors run into thousands of dollars a year. It will pay you to get the full story of raising power factor with capacitors. Just write for Bulletin GEA-5632, "How to Use Capacitors," to the General Electric Company, Section 441-112, Schenectady 5, N. Y.

Progress Is Our Most Important Product

GENERAL ELECTRIC

George L. Standring Memorial Hospital, Electrical Contractor—American Electric Company

Build

The electrical requirements of a modern hospital depend upon a quality wiring job for unfailing efficiency.

Metal raceways of Rome-EMT and conduit provide orderly arrangement of circuits as well as permanent protection.

reputation with quality
like this Seattle contractor did

New hospitals, manufacturing plants, public buildings, shopping centers are *news*. They bring business-building local publicity to participating contractors via the papers, radio, TV, public inspection and word-of-mouth.

"Free advertising" for American Electric

Around Seattle, for instance, door-opening day at the George L. Standring Memorial Hospital occasioned much fanfare and public interest. Firms like Clem Morisette's American Electric Company reaped a wealth of free publicity—justly so, because they did a good job.

One source—one responsibility

Mr. Morisette had the contract for the installation of all wire and conduit. Through his electrical distributor, he specified his requirements from one source, Rome Cable. Rome's Seattle office worked hand in glove to make his job easier . . . a typical feature of Rome's personalized service.

Quick availability of requirements, plus teamwork of Rome's representative, helped Clem Morisette (left) complete his electrical contract efficiently.

Now, power for operating rooms, theraupeutic equipment, and lighting flows—safe from interruption — through some 350,000 feet of Rome Synthinol® Type TW thermoplastic wires and cables protected within Rome-EMT thinwall conduit.

Rome·EMT cuts installation costs

The slick inside finish (Rome-EMT is easier to fish than any competitive thinwall conduit on the market) cuts fishing time, saves valuable man hours. Designed for one-man handling, with threadless compression joints, Rome-EMT was easy to work and install, too.

Rome Synthinol Type TW speeds wiring

The waxy-smooth thermoplastic surface and small diameters of Rome Synthinol Type TW help save time, make it clean to handle . . . easy to strip . . . easier to pull. Fully approved by Underwriters' Laboratories, Inc., Rome Synthinol building wires resist moisture, heat (even flame), oils and chemicals.

Many electrical contractors get the *same* advantages of Rome one-source responsibility and product quality which helped Mr. Morisette do a reputation-building job in Seattle. Rome Cable's sales representatives across the country stand ready to help you. Our engineers will be glad to study your wiring problems.

Write direct for information, or contact your nearest Rome Cable representative.

For helpful data on Rome Synthinol and Rome Synthinol 901 Type TW building wires and cables, write for Bulletin TW-1. Free. No obligation.

Rome sales offices are located in:

Atlanta, Ga.
Boston, Mass.
Chicago, Ill.
Cleveland, Ohio
Dallas, Texas
Denver, Colo.
Detroit, Mich.
Houston, Texas
Kansas City, Mo.
Los Angeles, Calif.
New Orleans, La.
New York, N. Y.
Philadelphia, Pa.
Pittsburgh, Pa.
St. Louis, Mo.
St. Paul, Minn.
Salt Lake City, Utah
San Francisco, Calif.
Seattle, Wash.
Tulsa, Okla.

It costs less to buy the best

ROME CABLE Corporation
ROME · NEW YORK
and
TORRANCE · CALIFORNIA

the grounded portable lighting

for modern plants

McGill 5000 series grounded service lights feature the convenience outlet and plug adopted as standard by Underwriters' and the National Electrical Code. Blade arrangement includes parallel blades and U shaped third blade for ground. This heavy duty portable and any attached power tools are completely grounded. Molded phenolic handle is heat and impact resistant and positively insulated. Heavy wire cage featuring end lens is zinc plated with chromate finish. Available with or without black rubber 16-3-SJ cord and Levolier Switch.

McGILL 5025-SLRG

NEW!

McGILL 7000 series

gray handle portables with

NEOPRENE-BUTYL

for greater grease resistance

Distinctive in appearance, the new, gray, neoprene-butyl handle offers superior grease resistance, won't rub off, mark walls, clothes or floor. Retains shape and resists deterioration under any service conditions.

No. 7000-SR Lamp Guard

all are McGILL quality

water-tight vapor-tight and moisture proof

portable lighting

These 3000 series McGill Vaporproof portables are used extensively in flour mills, elevators, ships, food processing plants and warehouses to eliminate hazards of shock, glass splinters and sparks from broken bulbs. A heat and impact resistant globe seals against the molded phenolic handle to guard the bulb from splashing liquids. The best in protective portable lighting available in 60 or 100 watt bulb size with either metal or fibre cages.

McGILL 3006

NEW portable

for spot or flood lamps

Designed in two sizes for 75 or 150 watt spot or flood lamps this new series offers an especially durable portable that throws light into ordinarily inaccessable places. Cages available for both PAR-38 or R-30-75 lamps on a pliable rubber handle, are standard with or without Levolier switch. The newest thing in dependable portable lighting. Underwriters' approved as are all McGill Portable Lamp Guards.

McGILL 7000-30

McGILL®

ELECTRICAL SPECIALTIES

are always a little better and **ALL** *are Underwriters' Laboratories Inspected*

Available through leading Electrical Wholesalers

For complete information on McGill Electrical Products, write today for the new Catalog No. 84.

McGILL MANUFACTURING COMPANY, 450 N. Lafayette Street, Valparaiso, Indiana

OVER 70 YEARS EXPERIENCE

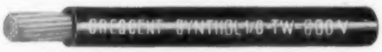
CRESCENT

Insulated Wires and Cables

Pictured and described here are just a few of the many wires and cables that are made by CRESCENT

ABC ARMORED CABLE

Has prefabricated breaking lines which make installing easier, quicker and safer. A flattened bonding wire in contact with the underside of each convolution of the armor assures a permanent law resistance of armor.



SYNTHOL BUILDING WIRE—TYPE TW

For both wet and dry locations. Insulated with a special, tough thermoplastic compound. High dielectric and mechanical strength. Smallest outside diameter for same conductor size permits more or larger conductors in same space.

ENDURITE BUILDING WIRE—TYPE RH-RW

A dual purpose wire, for either dry or wet locations. Type RH has a greater carrying capacity because of higher permissible operating temperature, which allows use of smaller size cable at less cost.

IMPERVEX TRENCHWIRE—TYPE USE-RR

Single conductors for direct earth burial. Has a heavy Neoprene jacket over the rubber insulation. Provides low cost, permanent underground cable installation.

STEEL TAPED PARKWAY CABLE

Designed for direct earth installation without additional protection. All standard types regularly supplied and special type cables made to customers' specifications.

IMPERIAL PORTABLE POWER CABLE

Illustration shows Type SH-D 5000 Volt Trailing Cable for supplying power to electric shovels, dredges, etc. Covered with extremely tough Neoprene jacket.

TYPE UF AND TYPE NMC

Used for direct earth burial as an underground feeder, also used for branch circuit wiring in damp or corrosive locations.

BUILDING WIRE—TYPE RHW

Braid or Neoprene Covered

Highest quality insulation, for use in both WET and DRY locations at 75° C.

CRESFLEX

Most suitable, lowest cost for rural, residential and farm buildings. Clean, gray paint finish.

SERVICE CABLES—TYPE SE

Both Style A (armored) and Style U (unarmored) are approved by Underwriters Laboratories as service entrance cable and may be run down the side of a building without additional protection. It is tamper-proof, flexible and lightweight, moisture-resistant and flame-retarding.

NEOPRENE CRESCORD

Heavy duty, oil-proof portable cord, Underwriters' Laboratories Type SO.

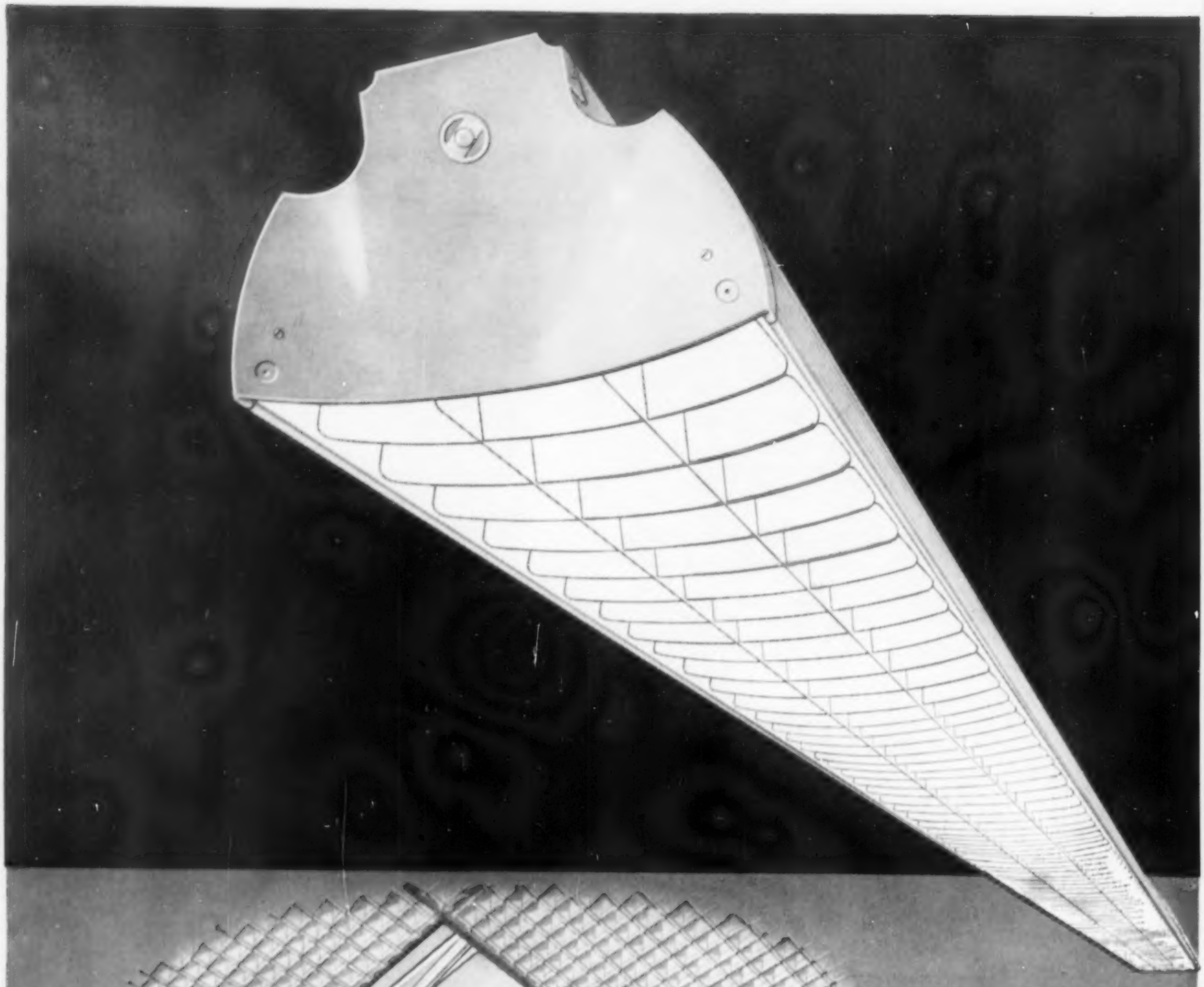
FLEXIBLE STEEL CONDUIT

Underwriters' Laboratories Standard.

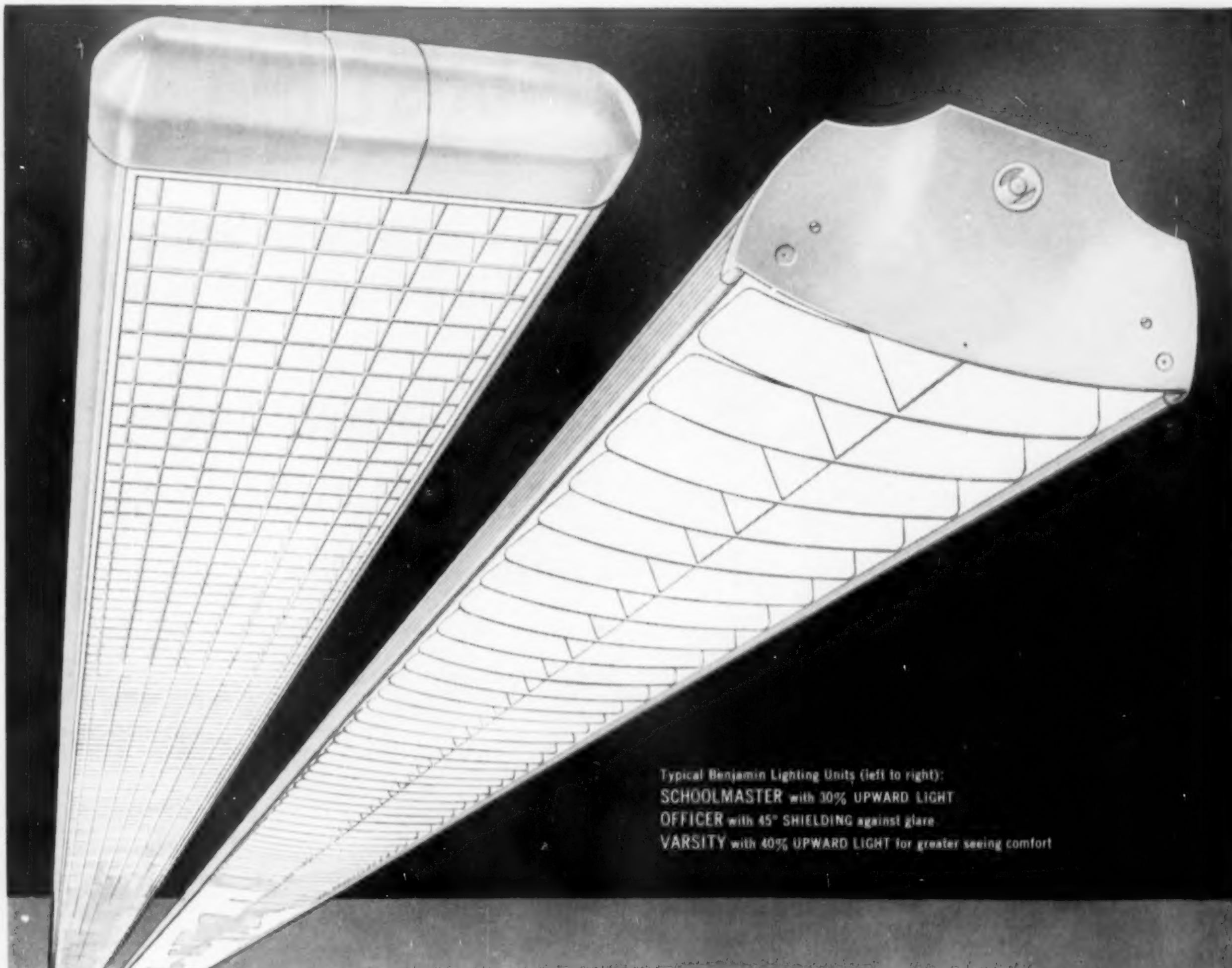
VARNISHED CAMBRIC LEAD ENCASED CABLE

Varnished cambric insulation has high dielectric strength and long life. Not affected by oils and greases. This cable is supplied with lead sheath for wet locations or weather-proof braid for dry locations.

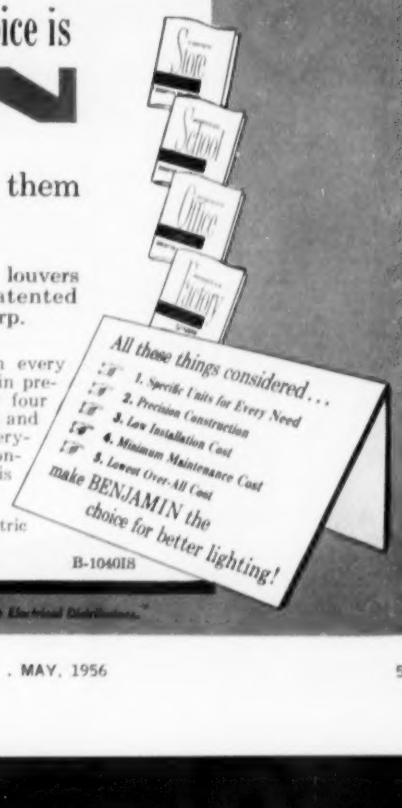
CRESCENT INSULATED WIRE & CABLE CO.
TRENTON, N.J.



1 Precision Construction of Benjamin Sky-Glo system also enhances the beauty of the installation. Exact fit of all sections is assured.
2 Finishing strips provide a neat edge to finish off the job.
SUSTAINING MEMBER



When all things are Considered, the Better Lighting choice is BENJAMIN



Compare Construction features like these; you get them all in the new Benjamin Lighting Units:

• **no fiddling with fancy louver hinges and catches:** Simple piano hinge and quick-action catches assure trouble-free opening and closing of louvers.

• **no "swing and sway" installations!** Benjamin precision construction assures accurate alignment of units . . . embossed channels for extra rigidity.

• **no lost motion or manpower!** All the knockouts needed are there and are conveniently located . . . no need to drill new mounting holes, either.

• **no plastics problems!** Plastic louvers are precision-molded by a patented process—always fit, will not warp.

Scores of advantages like these in every Benjamin unit are proof of Benjamin precision construction. Add the other four major areas of Benjamin superiority, and you will agree with leading users everywhere that "when *All* things are considered, the Better Lighting choice is Benjamin!"

Send for one or more of these Free lighting booklets. Write: Benjamin Electric Mfg. Co., Dept. H, Des Plaines, Ill.

B-1040IS

Incombustible...

That's why TRANSITE® DUCTS confine burn-outs and protect adjacent cables

DESPITE modern precautions, the burn-out is still a potential hazard. Consequently, cables should be given the maximum fireproof protection that Transite Ducts provide.

Transite Ducts confine burn-outs, safeguard adjacent cables from damage and reduce the possibilities of panic and explosion because they are incombustible throughout. Made of nonflammable asbestos and cement, Transite Ducts will not burn, smoulder or generate smoke or fumes. They cannot contribute to the formation of explosive gases.

Nowhere is the fireproof protection of Transite Ducts so necessary as in such vital locations as subways, tunnels and power plants.

As the panel below shows, incombustibility is only one of the advantages of Transite Ducts. For more information, write Johns-Manville, Box 60, New York 16, N. Y.

4 OTHER REASONS WHY TRANSITE DUCTS DO A BETTER JOB AT LESS COST:

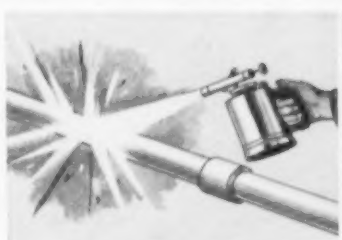
1. Corrosion-Resistant. Transite, being made of inorganic asbestos and cement, resists corrosion and is immune to electrolysis.

2. Permanently Smooth Bore. Transite makes long cable pulls easy. Danger of damage to cables is also minimized.

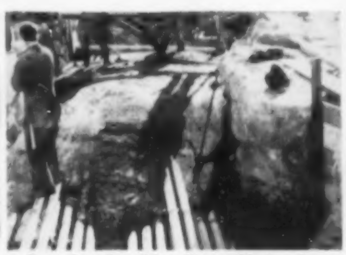
3. Easy To Install. Transite Ducts are light weight, easy to handle. Joints are quickly made. And long 10-ft. lengths reduce the number of joints in line.

4. High Thermal Conductivity. Cables run cooler in Transite, reducing I^2R losses, increasing current capacity and prolonging insulation life.

In Subways, where passenger safety is paramount, fireproof Transite Ducts will, in the event of a burn-out, confine it and reduce the hazard of panic.



Transite Does Not Burn, smoke or fume because its ingredients, asbestos and cement, will not support combustion. It cannot contribute to the formation of explosive gases.



Transite Provides Heat Dissipation, Too. In addition to providing fireproof construction, Transite Ducts permit cables to run cooler, reducing I^2R losses.

Photograph courtesy of Triborough Bridge and Tunnel.

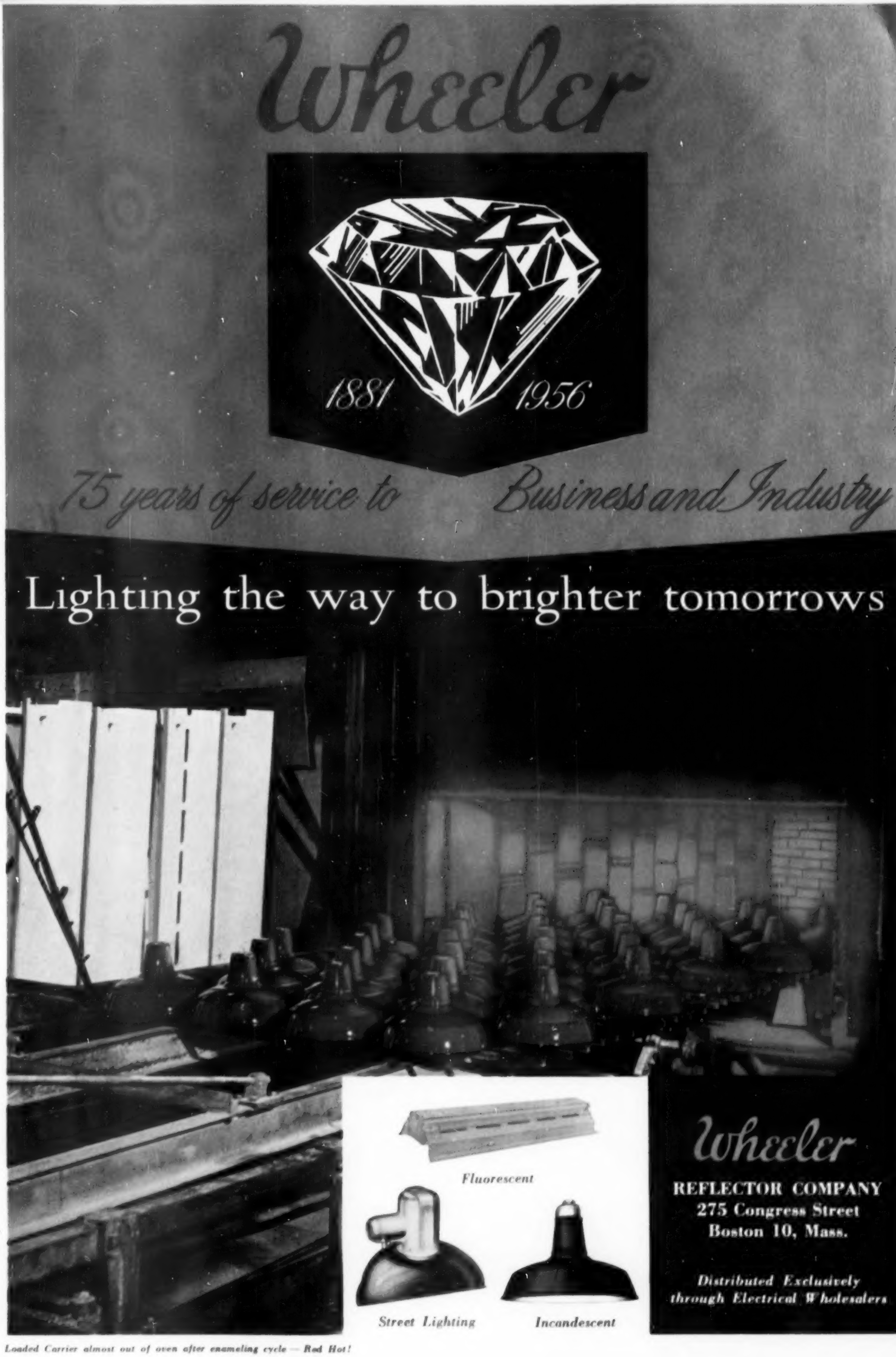
In Vehicular Tunnels, if a burn-out should occur, Transite Ducts limit damage, permit speedier repair and an earlier re-opening for traffic.

Johns-Manville TRANSITE DUCTS

JOHNS-MANVILLE JM PRODUCTS

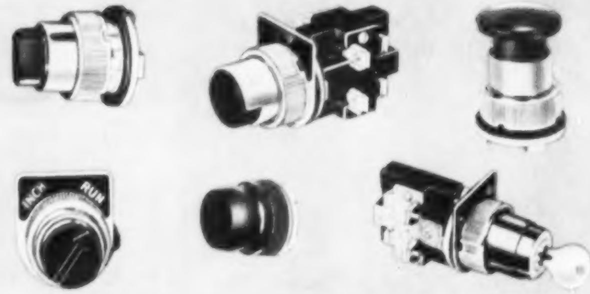
TRANSITE KORDUCT—for installation in concrete

TRANSITE CONDUIT—for exposed work and installation underground without a concrete encasement



Loaded Carrier almost out of oven after enameling cycle — Red Hot!

Oil-Tite* Control Station
. . . 1 to 16 units

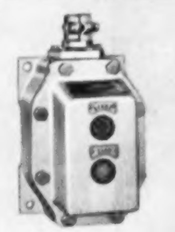


Standard Components Available

Standard Duty
Available in one, two and three unit stations.

Heavy Duty
Comes in a choice of from one to seven unit stations.

Pendent Type
In standard, heavy duty and Oil-Tite enclosures.



Special Service
Units for mining, steel mills, extra heavy duty.

Get delivery now on complete Westinghouse pushbutton line

The most complete selection of pushbutton units in the industry—for standard or heavy duty, oiltight, pendent-type, and corrosion-resistant applications—now available for immediate shipment.

Standardized and interchangeable component parts quickly give you the right pushbutton for every application. Even the latest additions to the Westinghouse pushbutton line such as the new and unique Push-to-Test indicating light, which permits an immediate check for burned-out bulbs, are always available right "off the shelf". Immediate delivery also available on a choice of enclosures for surface, flush or pendent mounting—for indoor, outdoor, water and dust-tight, oil-immersed or corrosion-resistant applications.

Order Westinghouse pushbuttons *today*—get 'em *tomorrow* (or sooner), right off the shelf. Call the control sales engineer at your nearest Westinghouse office, or write Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pa., and ask for descriptive bulletin 15-000. J-30191-A

*Trade Mark

YOU CAN BE **SURE**...IF IT'S
Westinghouse

Loaded Carrier almost out of oven after enameling cycle — Red Hot!

"INCH-MARKS"—Help you avoid clumsy problem of a flat rule on a round tube. Each inch and foot of tubing is clearly marked to permit easy measurement of exact length. Speeds up cutting and bending operations. On sizes ½", ¾", 1" and 1¼". Always ask for "Inch-Marked"—the mark of quality.

JOINING IS QUICK AND EASY. There are no threads to cut, no lines to turn. To make joints tight, just turn the nut, not the entire run. Runs fixed at ends can be joined in the center without turning the run, using a standard compression coupling. On concrete-pan jobs, boxes with connectors attached prior to spotting make accurate location of outlets easy. Runs are quickly attached without lifting the box.

Republic "Inch-Marked" E.M.T.

You don't have to worry about a pocket full of wet concrete when you work with Republic ELECTRUNITE® E.M.T. It goes in so smoothly you can't help staying ahead of schedule.

The reason: Republic E.M.T.'s *exclusive* features that simplify the job from planning to wire pulling.

Measuring distance is easier because the entire length of tubing is marked in inches and feet. Bends are easier to make accurately—and without costly "wows"—due to the handy, longitudinal guide line. Wire pulling is almost effortless because of the knurled "ball-bearing" inside surface of the tubing—another Republic exclusive.

Republic ELECTRUNITE E.M.T. makes it easier to meet schedules for any type of construction. For concrete-slab construction it's 100% approved by the National Electrical Code.

Keep the concrete boys off your back, and at the same time reduce costs by installing Republic E.M.T. Just ask your electrical distributor for the E.M.T. that's "Inch-Marked"® and "Guide Lined." Send coupon for literature providing complete information.

STEEL

and Steel Products

REPUBLIC STEEL CORPORATION
Steel and Tubes Division
Dept. C-1909
212 East 131st Street • Cleveland 8, Ohio

Please send me more information on:

☐ ELECTRUNITE "Inch-Marked" E.M.T.

☐ Bending Instructions (Handy Wall Chart)

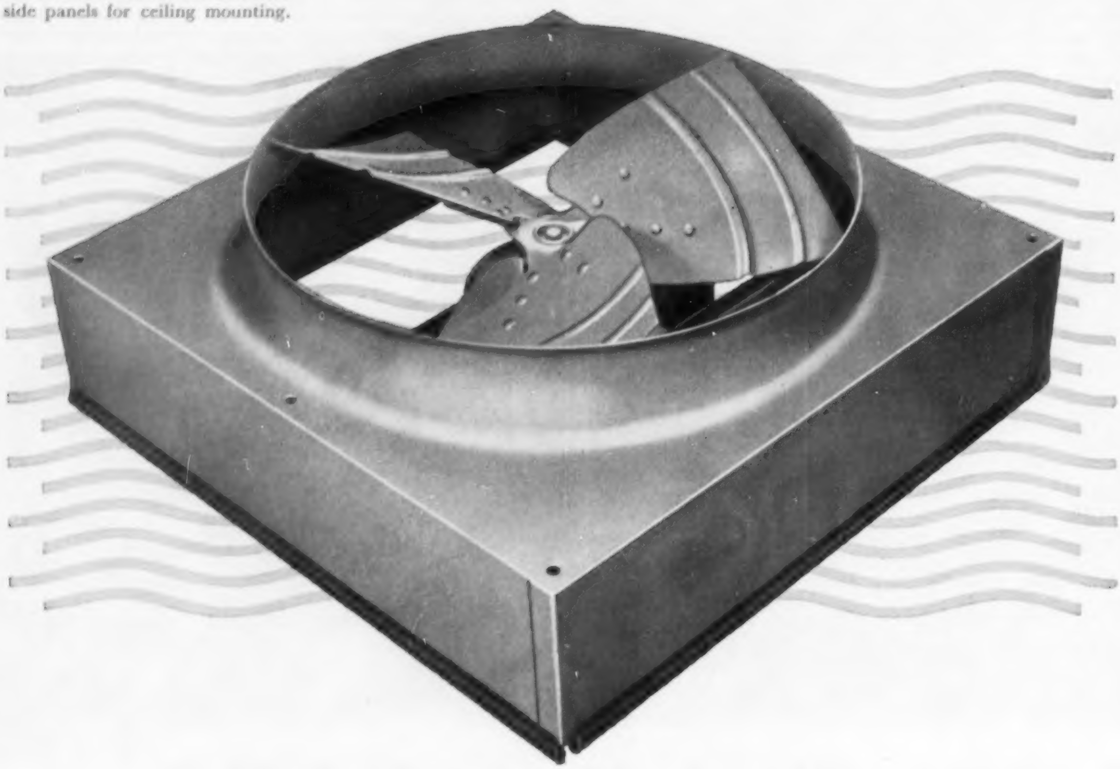
Name________ Title________

Company________

Address________

City________ Zone____ State________

Model CA Ventura Attic Fan with side panels for ceiling mounting.



New dual-purpose attic fan is easy to stock, simple to install!

We call our new Model CA Ventura Attic Fan *dual purpose* because it can be used for either ceiling or wall mounting in the popular 24-, 30-, and 36-inch sizes.

The secret? The basic fan is available with side panels and rubber cushion strips — accessories which convert it from a vertical to a horizontal fan in a matter of minutes right on the job.

This dual-purpose feature makes installation a cinch — not to mention the big reduction in inventory it permits! Hardware and instructions are included with each side-panel set.

American Blower offers a *complete line* of fans — propeller fans, home ventilators, utility sets . . . a good reason why it pays to *standardize* on American Blower.

Why not call our nearest branch today for full information.

IT PAYS TO STANDARDIZE ON THE AMERICAN BLOWER LINE!

- **Attic Fans** for comfort cooling at low cost in homes, apartments, hotels. Ratings certified; vertical or horizontal models.
- **Aeropel Home Ventilators** for kitchen use, or small commercial ventilating jobs. Attractive design; quiet; easy to install.
- **Ventura Fans** for efficient commercial and industrial ventilation; propeller type; 10 to 72 inches. Certified ratings.
- **Utility Sets** for general supply or exhaust duty. Ratings certified; self-contained. Sirocco wheels, 3 to 36 inches.

AMERICAN BLOWER

Division of American-Standard

AMERICAN BLOWER CORPORATION, DETROIT 32, MICHIGAN • CANADIAN SIROCCO COMPANY, LTD., WINDSOR, ONTARIO

ONE *Complete* SOURCE

for the finest in

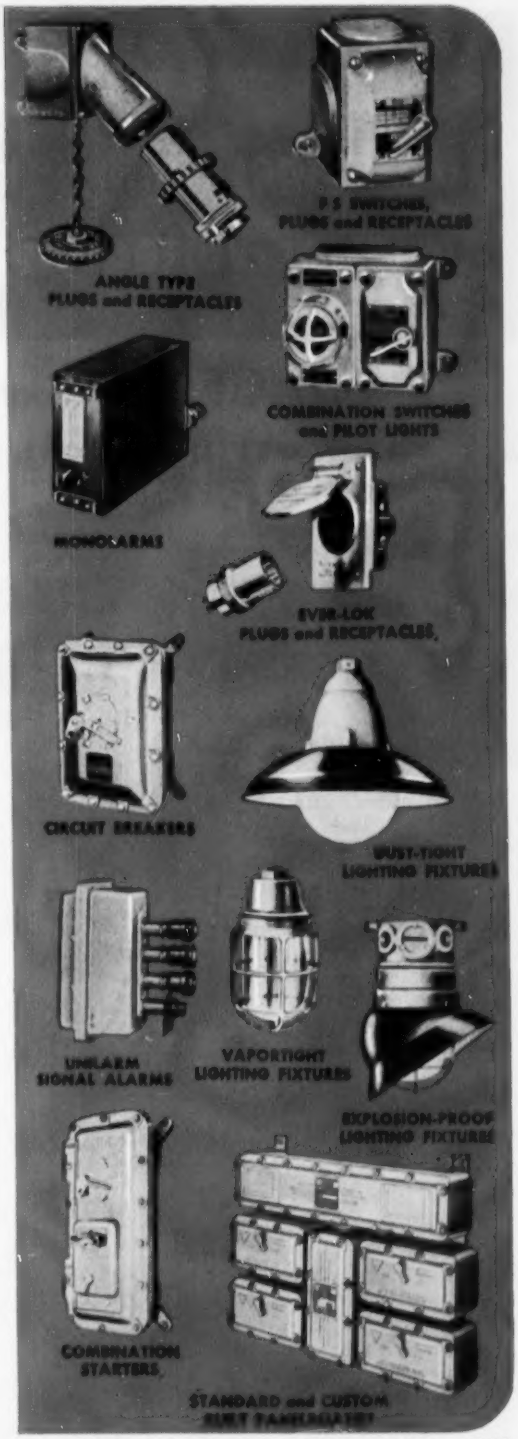
ELECTRICAL EQUIPMENT
for
HAZARDOUS LOCATIONS

EXPLOSION-PROOF • DUST-TIGHT
VAPORTIGHT • WATER-PROOF

Design leadership, precision manufacture and rugged quality are three important features that make R & S electrical equipment for hazardous locations, the standard of comparison. Made of materials of outstanding quality, by highly skilled craftsmen, R & S electrical equipment is known and respected by architects, contractors, designers, engineers and maintenance men in all types of industries. Electrical wholesalers prefer to list and sell R & S equipment because these products create prestige, satisfy customers and promote greater sales. Feature for feature, item for item, there is nothing finer for hazardous locations than the R & S complete line.

If you are concerned with the proper application of electrical equipment to eliminate dangers in your hazardous locations, let R & S help you solve any problem.

Sales Representatives in Principal Cities

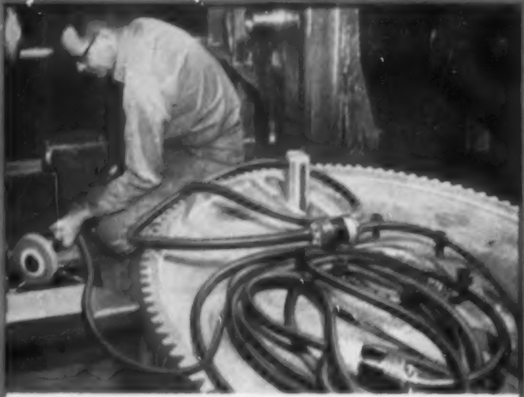


RUSSELL & STOLL COMPANY, INC. • 125 BARCLAY STREET, NEW YORK 7, N. Y.
D-15

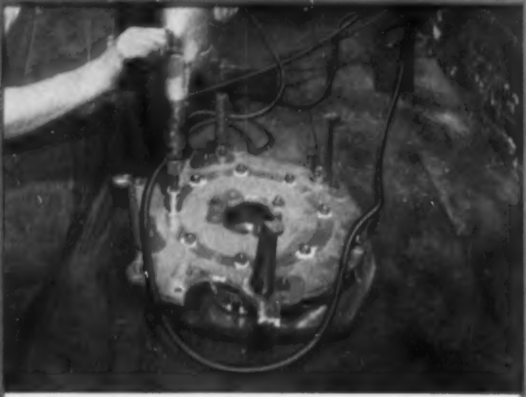
RUSSELL & STOLL

PRECISION-BUILT ELECTRICAL EQUIPMENT—SINCE 1902

Laytex® Royal Master Electrical Cords



Portable grinder equipped with U.S. Laytex Royal Master Cord. Note that it must resist dragging over sharp metal edges . . . and its extreme flexibility.



Electric wrenches equipped with U.S. Laytex Royal Master Cords apply studs to bottom base of braider. Cords resist chemical action of oil, white lead.

Hand-drilling hole in a braider. Note the high flexibility of U.S. Laytex Royal Master Portable Cords in confined spaces.

"The answer to a plant electrician's dream . . ." says a leading maker of braiding machines.

"Before June 1954, we were repairing and replacing the electrical cords on our portable electric drills, wrenches and grinders every six months," says the plant's chief electrician. "The cord jackets were easily bruised and weakened, or even cut. What with being dragged over the floor and around sharp intersections, any tape repairs didn't last long. Then, there were fire hazards and chances of blowout.

"When U.S. Laytex Royal Master Portable Cords were demonstrated to us, and installed, the problem was licked. The cords have a jacket that stands up under our most demanding conditions—and even though their internal wires, insulators and separators are heavily reinforced, the cords still have high flexibility.

"Our men usually pick up the tools by grasping the cord as a handle. Standard cords pulled loose after a short time, because of inability to take constant flexing, and support weight of 15-25-pound tools. We've found that not one U.S. Laytex cord has pulled loose since installation."

U.S. Laytex Royal Master Cords are unquestionably the crowning achievement in portable cords, unsurpassed in performance *and* economy. Obtainable from your "U.S." branch, your distributor, or write us at Rockefeller Center, New York 20, N.Y.

Electrical Wire & Cable Department

United States Rubber

ELECTRICAL CONSTRUCTION AND MAINTENANCE

55th Year—May • 1956

Made-to-order

You asked for it. Here it is. This issue contains the biggest single editorial project we have ever tackled. The subject, "Modern Electrical Systems Design," is one on which there was no comprehensive, practical manual available. Handbooks cover the subject only briefly; textbooks academically; and trade literature is devoted primarily to product application. While such sources are valuable and authoritative, each in its own scope and objective, the task of bringing together basic data and considerations leading into practical systems design has not been, heretofore, achieved on a sufficiently comprehensive scale.

The need was obvious. The crucial importance of good system design is recognized today in every segment of the electrical industry. But what is good design? For any one job there are probably several satisfactory systems. The choice more often involves judgment than formula. Therefore, there is a distinct and useful place for a practical, interpretive, published work setting forth the criteria of good design in the context of actual current practice.

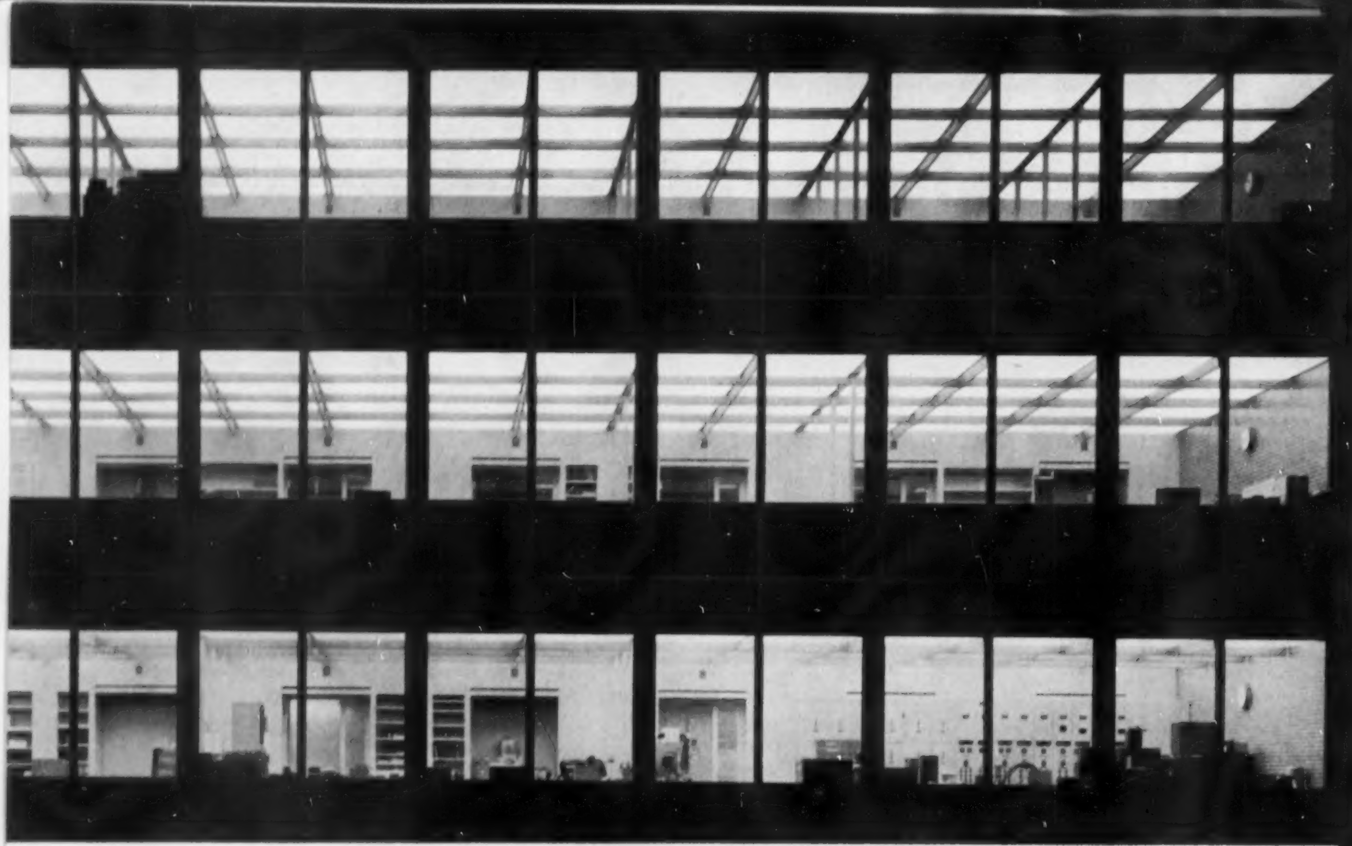
There are many engineers well qualified to prepare such a project. But it takes large resources, much time and expert help to reach the printed page. Our editorial staff had several distinct, even unique, advantages: an unexcelled file of source literature, expert service facilities, and virtually daily, first-hand, contact through broad travel with actual and current electrical work in all parts of the United States.

About a year ago, we made the decision to proceed with the project. The task was outlined in depth and assigned to members of the editorial staff who could bring to bear seasoned experience and sound interpretation. The proceeds are brought together in the special report to which we have devoted most of the editorial pages of this issue.

This project was literally made-to-order for the subscribers of Electrical Construction and Maintenance and presumes that the reader is professionally or practically concerned with the subject. It is not intended as a text for untrained or inexperienced persons. A working knowledge of codes and regulations, construction practice, and of electrical materials, equipment and installation methods, is essential background.

For the editors, it has been an exacting and often difficult job. But we believe that the potential usefulness, value and benefit of this work to you, the reader, are going to be worth much more than the cost and toil that it took to place it in your hands.

Wm. T. Stuart



ELECTRICAL CONSTRUCTION AND MAINTENANCE

An original manual on practical design and layout of . . .

Modern Electrical Systems

THIS special report has been prepared as a guide and reference source for designers of electrical systems. Although phases of electrical design are covered in many books, booklets and magazine articles, this report is a treatment of the *complete art* of electrical design. The presentation goes into design of complete electrical systems for a wide range of industrial, commercial and institutional buildings. From specific electrical loads and the circuits to serve them, down to connection to main power supply lines, this article incorporates the many design considerations and relates all parts to the whole.

Aimed at the ever-increasing need for modern electrical design data, this report covers accepted practice and emphasizes design trends which have particular merit. Over and above sound engineering principles and intelligent conformity to the safety provisions of the National Electrical Code, the basis for this report includes due recognition of substantial spare capacity as an essential element of modern electrical design. Following the table of contents given on this page, the material is presented within a framework of three steps to design of any electrical system, as follows:

1. Select basic wiring concepts and configurations which will supply electrical power of the required characteristics at each point of electrical utilization, including circuit and distribution designs which will provide satisfactory transfer of power from source to loads to meet prevailing requirements.

2. Implement the electrical circuiting concepts with actual conductors, apparatus and hardware, selecting types, sizes, models, characteristics, appearances, ratings and other specifics of the required equipment.

3. Account for the installation of the overall electrical system, as determined from the first two steps, within the physical dimensions and structural makeup of a building, showing, as clearly as possible, locations and details of equipment mountings, raceway runs, connections to main power supply lines and whatever elements require special attention.

Of course, these three steps are necessarily interrelated, and particular decisions made within any one step will affect corresponding elements within either or both of the other steps.

As can be seen from the three steps, design of an electrical system is expressed in the form of electrical plans. All phases of a design, including design of sub-systems within the major system, should be reduced to a set of blueprints which present schematic wiring diagrams, single-line diagrams, full-wiring hookups, riser diagrams, isometric and other sketches, detail drawings and equipment schedules—all as necessary to convey a clear picture of the system to the installer.

To complement the plans of any electrical system design and to implement realization of the engineering concepts, a set of electrical specifications should be prepared (May 1955, *Electrical Construction and Maintenance*). Together, plans and specifications must fully and clearly instruct the installer in constructing the overall electrical system.

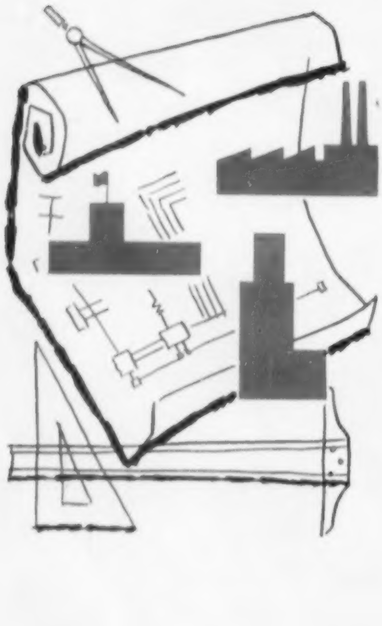
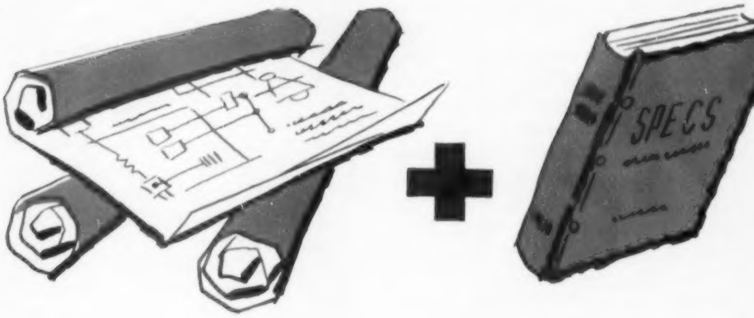


TABLE OF CONTENTS



INSTALLATION INSTRUCTIONS

General Considerations

CONSTANT development of new and better electrical equipment and rapid expansion in electrical utilization make electrical design a dynamic thing. As a result, the elements of modern electrical systems for power, light and heat are parts of a continually evolving technology. New patterns of distribution, circuiting and equipment layout no sooner appear than they undergo changes. Progress brings wiring techniques for lift-slab construction, 480/277-volt systems for commercial buildings, high frequency lighting and many other applications and methods affecting design. These developments in their turn become the source of even more design variations. An ever-expanding variety of wiring methods and equipment is one of the most significant characteristics of modern electrical design.

Overall growth in the use of electrical power has brought a wider choice of electrical system voltages, more types of systems suited to particular utilization requirements, increased standardizations in equipment types and ratings which have proved best for particular applications, gradual shift toward modular cabinet assemblies of interchangeable panel units, closer relation between equipment characteristics and special application requirements, advances in techniques and equipment for electrical control and greater appreciation for such system characteristics as accessibility, flexibility, allowance for load growth, regulation and safety.

Many electrical design techniques which only a few years ago were trends are now firmly established as accepted practices. These include: primary distribution with load center substations, complete busway electrical systems in industrial plants, 480/277-volt power and light distribution systems in commercial buildings, low-voltage relay switching of circuits and the use of all-electric ceilings in which electrical wiring and raceways are carried above a suspended-ceiling lighting system. And other factors such as recent improvements and new developments in static type rectifiers for providing large blocks of dc power at near 100% conversion efficiency, the fast growing necessity of air conditioning and the application potential of electric heat are already influencing electrical design methods.

Because modern electrical design is the product of years of accumulating technology, the electrical system designer must be thoroughly familiar with the broad background of design as well as new techniques and promising trends. Successful electrical design is not a mechanical proposition of merely filling-in formulae and adding parts together. It involves clear understanding of old, accepted techniques and the reasons why those techniques survived the test of years of application. It requires "imagineering" in the combination of old and new wiring techniques and the ability to devise original circuits and layouts for new or special equipment applications. Only from an all-around grasp of the subject can a designer exercise judgment in selection of circuit and feeder arrangements, equipment types and ratings and mounting and installation methods. In fact, it is the confident, imaginative electrical system designer of today who will be molding electrical designs of tomorrow.

Simply stated, electrical design for industrial, commercial and institutional buildings is a matter of providing for the transfer of power from a source (or sources) to various utilization loads. This involves selection and layout of circuits to feed the loads, a distribution system to serve the circuits and suitable switching and protection arrangements for the incoming power supply lines. But before the actual design work begins, there are many factors which must be considered and understood in their relation to the contemplated design of an electrical system.

Pre-Design Factors

Any electrical design must of course conform to the provisions of the National Electrical Code. The code (throughout the article, the word "code" refers to the National Electrical Code) sets forth requirements, recommendations and suggestions and constitutes a minimum standard for the framework of electrical design. As stated in its own introduction, the code is concerned with the "practical safeguarding of persons and of buildings and their contents from hazards arising from the use of electricity for light, heat, power, radio, signalling and for other purposes." Although its relation to electrical design is in establishing the basic minimum provisions essential to safety, the code should not be taken as a design or installation manual. This is particularly important in that the code provisions are not necessarily consistent with efficiency, convenience, flexibility or adequacy in design.

A thorough understanding of the code is, then, essential to the execution of any modern electrical design. The electrical system designer must be familiar with all sections of the code and the accepted interpretations which have been placed on many specific rulings of the code. Again, however, the code must be used only as a safety guide; it must not be regarded as the source of electrical design. Electrical design must come from the engineering skill, experience and imagination of the designer, who uses the code only as a tool in shaping rough design.

Load Growth

One of the most important considerations in design of any electrical system today is the allowance for growth in the load the system must handle. Although the code contains an almost obscure recommendation that electrical plans and specifications include "allowances for future increases in the use of electricity", experience with current electrical modernization practice indicates that lack of spare capacity plagues existing systems. In all types of buildings, conduit risers are filled to capacity and the conductors in them are either loaded fully or overloaded. In most commercial and institutional buildings, the entire electrical system is at or near saturation—in branch circuits, feeders and service. And in the majority of these buildings, modernization of the existing electrical system to handle increased load demands is impeded by absence of space in which new risers and circuits might be run. It is obvious that overall design of these electrical systems did not account sufficiently for future load growth.

Modern electrical design, therefore, must carefully plan for future increase in electrical utilization. Depending upon the particular conditions in any installation, mains, switchgear, transformers, feeders, panelboards and circuits should be sized to handle considerable load growth. Conductors should be selected on the basis of carrying capacity, voltage drop and estimated future requirements. Conduit, wireways, troughs and other raceways should be sized to allow future increase in occupancy. And space used to house electrical equipment—electric closets, switchgear rooms, substation cages, riser and pipe shafts, etc.—should also be able to accommodate the addition of more equipment at a later date.

Service Characteristics

Another preliminary consideration which fundamentally affects design procedure involves the characteristics of the power supply which will serve the building's electrical system. The power supply may be either the distribution system of the electric utility company of a private electric generating plant. Of course, a utility power system is the most common type of supply to buildings and plants. Purchase of energy usually represents decided economy over the cost of private generation of electric energy within the building or plant. Of course, there are certain cases, such as paper and pulp mills, in which requirements for large amounts of process steam make possible the use of excess steam for economical generation of energy. In such cases, the generating plant may be operated independently of a utility supply to the building or in parallel with it. If the local generating plant operates independently, part of the total electrical load may be connected to it and part to the utility system. Use of a generating plant in parallel with a utility supply must be checked with the utility company engineers. Selection of a parallel combination of power generated on the premises and power purchased from the utility depends upon favorably resolving such problems as the maintenance of synchronous operation of the two parallel supplies and the protection of both supplies against circuit faults and interruptions.

If power is obtained from a utility line, the characteristics of the supply must be matched to the requirements of the building. Depending upon the voltage and capacity of the supply, one particular type of distribution is often best suited to carrying the electrical loads in the building. Purchase of power at utilization voltages indicates certain types of distribution; higher voltage services and primary supplies also indicate their own types of distribution systems within the building. When several different supply voltages are available, each should be appraised in relation to the various distribution methods which might be used. Consultation with the utility company about the type of service to select and the relation between different services and interior distribution systems should precede any decisions. And during the course of the design work attention should be given to the rules of the utility insofar as they might affect the system—such as power factor requirements and possible application of capacitors or synchronous condensers. Once the general details of a power supply have been decided upon, actual design—suitable connection to the power mains, method and layout of distribution and circuiting to loads—can be started.

Occupancies and Loads

The general design approach to any contemplated electrical system takes into account the type of building—small or large, single-story or multi-level industrial plant; high office building; apartment house; single-or multi-level school; hospital; etc.—as this gives insight to types of electrical utilization, need for flexibility, accessibility of the system and the duty

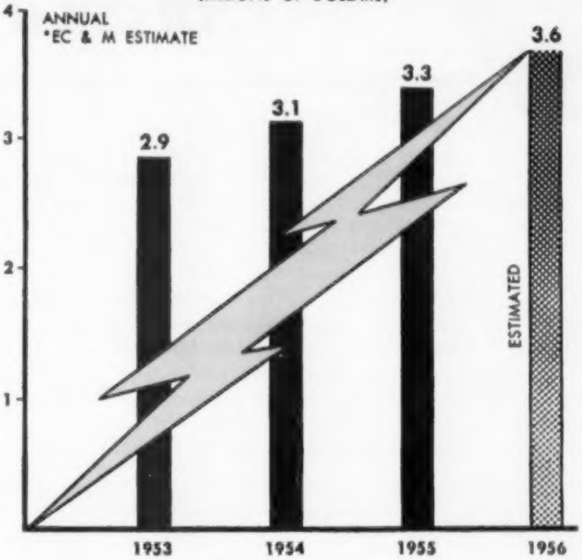
cycles of various load devices. The many and varied considerations for hazardous locations also serve to give direction to design approach. From the general approach, the mind of the designer should have selected many design possibilities which suit the particular building and have rejected all methods and techniques which are immediately not applicable.

In general, planning for design of an electrical system should begin with determining and studying the size and nature of the total load to be served. This means approximation of lighting loads on the basis of watts/square foot, analysis of number and sizes of motors served in various areas of the building and determination of amount of other utilization loads and their concentrations throughout the building. Full understanding of all loads—their values and points of application—is essential to selection of the best type of distribution system.

Maximum standardization in equipment type and ratings should always be a design objective. Selection of standard supply voltage and standard values at all voltage levels is a significant economy factor in that standard rated transformers, switchgear, motors and other equipment cost less than special equipment for non-standard voltages. Lack of standardization in an electrical system complicates maintenance in that replacement parts are not easy to get, inventory of parts and equipment is high and the efficiency of maintenance personnel is reduced. And the use of special, non-standard equipment and voltages may seriously impair expansion or alteration of the electrical system at a later date.

Electrical Construction Volume

(BILLIONS OF DOLLARS)



System Characteristics

In addition to those mentioned above, there are five other particular considerations which should precede initiation of actual design work. These concern:

1. Capacity
2. Regulation
3. Accessibility
4. Flexibility
5. Safety

Capacity—In general, every electrical system should have sufficient capacity to serve the loads for which it is designed, plus spare capacity to meet anticipated growth in the load on the system. In particular, this means that conductors and raceways—conduit, busway and troughs—must be sized liberally for computed loads; substations, transformers and switching and protective devices must have the needed capacity and ratings. And spare capacity throughout the branch circuiting should be reflected back through the entire electrical system to the point of power supply.

Regulation—Effective design of an electrical system must provide maximum possible voltage stability. Careful attention must be given to the load current and power factor on the one hand, and the resistance and reactance of conductors on the other hand. To assure maximum stability on feeders, minimizing voltage fluctuations due to load changes, conductors must be selected not only on the basis of their allowable current-carrying capacity for safe temperature rise but also on the basis of voltage drop in the conductors themselves. Locations of motors and machines in relation to the lengths of feeders to them and duty cycles of load devices in relation to load concentrations on individual feeders are factors in the determination of the best condition of voltage regulation. The important objective is to keep the proper voltage at each and every point of utilization as constant as possible for any conditions of loading or system disturbance.

Accessibility — Every electrical system should rate high in accessibility. In its final form, design of the system must provide ease of access to equipment for maintenance and repair and for any possible extensions, modifications or alterations in the system. The system of conductors, raceways and equipment must allow for full use of its power handling ability.

Flexibility—Depending upon the type of building—industrial, commercial or institutional—the electrical system must be designed to provide required flexibility in distribution and circuiting. Layout and type of equipment should readily accommodate changes in locations of motors and other utilization devices. Feeders, distribution panelboards and circuits should be suited to a wide range of utilization patterns, allowing full and efficient use of power capacity for activities in the building's various areas.

Safety—Compliance with the provisions of the National Electrical Code minimizes fire and accident hazards in any electrical design. Safety in an electrical system should apply to both personnel and equipment. Although the code assures minimum safety provisions, actual design work must constantly consider safety as required by special types or conditions of electrical application. Incorporation of automatic protective devices and selection of control equipment for particular applications involves engineering skill of the designer, above routine adherence to code requirements.

Branch Circuits

IN A WIRING system, a branch circuit is that part of the system extending beyond the final automatic overload protective device of the circuit. In its simplest form it consists of two wires which carry current at a particular voltage from the point of the protective device to an electrical utilization device or devices. The branch circuit represents the last step in the transfer of power from the service to utilization devices. Although consideration of service and distribution methods is usually emphasized in electrical design work, design of modern circuit arrangements is extremely important to successful design of the overall electrical system. Thorough understanding of the theory and application of modern circuit techniques is assured by a breakdown and careful analysis of the factors involved.

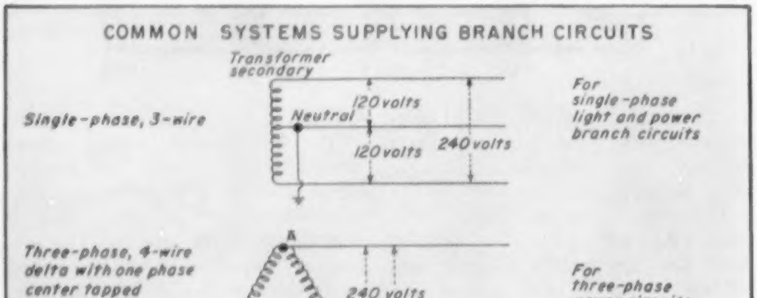
Design of branch circuits should take into account all of the general considerations essential to providing for modern load requirements. These include capacity, regulation, accessibility, flexibility and safety.

Each and every branch circuit—whether for power or lighting load, in commercial or industrial buildings—should be sized for its load, with spare capacity added where possible load growth is indicated. Design should also provide for economical addition of circuits to handle future loads. Regulation of each circuit must assure required power capacity at full utilization voltage at every circuit outlet.

Accessibility and flexibility are two important characteristics of effective branch circuiting. In commercial and industrial buildings, shifting of load devices as a result of tenant changes, rearranging of office layouts, changes in production schedules or relocation of production lines is common. Circuits in such areas must readily accommodate these changes and must allow extensions of the circuits.

Safety provisions in branch circuits are, of course, essential. Adherence to the provisions of the Code will assure basic safety. In providing circuits for special or unusual utilization devices such as might be encountered in research laboratories or for devices not covered in the Code, the designer must call upon his own engineering skill and perception in providing effective control, grounding and protection for maximum safety.

In general, modern branch circuit design has developed from the trend toward higher distribution voltages. As a result, branch circuits are short runs from strategically located transformer or substation load centers instead of long circuits from a central distribution center. The higher voltage is delivered to the load center where it is stepped to utilization levels. Aside from the many advantages load-center layout offers to distribution, the use of load centers and resulting short branch circuits provides better-regulated voltage supplies to utilization devices and minimum circuit disturbances due to load changes.



NOTES:

1. Other system configurations are commonly used to supply branch circuits, but they are derived from the basic systems shown. Particular local conditions and/or requirements for load balance throughout an overall system frequently dictate the use of less common derivations of branch circuits. Such arrangements include 120/208 3-wire feeds to branch circuit panelboards, open-delta three-phase supply to light and power branch circuits and other special transformer hookups supplying branch circuit loads.

2. Motor branch circuits may be served directly from high-voltage supplies.

Modern electrical systems use three basic types of branch circuit systems to serve utilization voltages to light and power outlets. These are derived from the common secondary distribution systems, as follows:

Single-phase, 3-wire system—This is a commonly used system in small apartment and commercial buildings. Both lighting and single-phase motor loads can be served, although the system is limited to use only where motor loads do not exceed 5 hp. Two-wire, 240-volt branch circuits can be used for power loads; 3-wire, 120/240-volt circuits for lighting outlets, split-wired duplex receptacles and some power devices such as electric ranges; and 2-wire, 120-volt circuits for lighting and receptacle outlets.

3-phase, 3-wire system—This is the common delta-connected secondary system with phase-to-phase voltage of 240 or 480 volts between each pair of phase conductors. This system is used where the motor load represents a large part of the total load. In some such systems, 3-phase 3-wire circuits at 480 volts feed individual motor loads, with single- or 3-phase step-down transformers from 480 to 120 volts used to supply lighting and receptacle circuits. In other 3-phase, 3-wire systems, 3-phase motors are supplied at 240 volts, with single-phase 240- or 120-volt branch circuits taken from a grounded, center-tapped phase of the system. In still other systems of this type, power circuits may be taken from the higher voltage, 3-phase distribution system, and the lighting circuits taken from a separate service and distribution system in the building.

3-phase, 4-wire system—This is the most widely used 3-phase secondary distribution system. The most common use of this configuration is the 120/208-volt, 3-phase, 4-wire system with the neutral grounded. With this system, a variety of circuits is available: 4-wire, 120/208-volt circuits; 3-wire, 120/208-volt circuits; 3-wire, 208-volt circuits; 2-wire, 208-volt circuits; and 2-wire, 120-volt circuits. Such a system can serve a combination of power and lighting loads and offers flexibility for circuit layout and application of utilization equipment. Another 3-phase, 4-wire, wye connected system which has gained rapidly in acceptance and application is the 480/277-volt wye-connected system (also called 460/265-volt system, due to the voltage spread). Under certain conditions, this system offers more advantages and economy in commercial building applications than the 120/208-volt system. The system makes available three types of branch circuits: 480-volt, 3-phase for motor loads; 277-volt, single-phase for fluorescent or mercury vapor lighting; and 120-volt or 120/208-volt circuits from step-down transformers for receptacle circuits and miscellaneous loads.

Lighting and Appliance Circuits

Design of a lighting layout for any commercial, institutional or industrial building includes determination of the required foot-candle intensity of lighting, selection of the general type of lighting—incandescent, fluorescent, mercury vapor or some combination of these, number of lamps per luminaire, number of luminaires, types of luminaires, mounting details, wiring methods and other specifics covered in the section of this report which describes lighting design. As a result of the lighting design for a particular area, a known value of required watts of circuit capacity is obtained. This value is used in determining the number of lighting circuits needed.

LOAD CALCULATIONS

BRANCH CIRCUITS – LIGHTING & APPLIANCE

Two-Wire:

$$I = \frac{\text{total connected load (watts)}}{\text{line voltage (volts)}}$$

I = current load on conductor (amperes)

Three-Wire:

Apply same formula as for two-wire branch circuit, considering each line to neutral separately. Use line-to-neutral voltage; result gives current in line conductors

Electric Range:

2-Wire Circuit: $I = \frac{\text{total connected load (watts)}}{\text{line voltage (volts)}}$

3-Wire Circuit: $I = \frac{\text{total connected load (watts)}}{\text{voltage between outside wires (volts)}}$

Ampere load on the neutral of a 3-wire circuit may be taken as 70% of that on the outside conductor.

Total connected load, or watt load, is the rated wattage of ranges or other cooking appliances up to 1¾ KW. For units rated higher than 1¾ KW, the value of watt load is determined from Table 29 of the National Electrical Code.

BRANCH CIRCUIT WIRING SYSTEMS

CABLE ASSEMBLIES

Flexible metallic armored cable — Code Article 334
Non-metallic sheathed cable — Code Article 336
Open wiring on insulators — Code Article 320
Mineral-insulated, metal-sheathed cable — Code Article 330

RACEWAYS FOR STANDARD WIRE AND CABLES

Rigid conduit — steel and aluminum — Code Article 346
Thinwall electrical metallic tubing — Code Article 348
Flexible metal conduit — Code Article 350
Liquid-tight flexible metal conduit — Code Article 351
Underfloor ducts — metallic and non-metallic — Code Article 354
Cellular metal floor raceways — Code Article 356
Surface metal raceways — Code Article 352
Multi-outlet raceway assemblies — Code Article 353
Wireways — Code Article 362

BUSWAYS FOR BRANCH CIRCUITS — Code Sections 3651 and 3652

2-, 3- and 4-pole plug-in and trolley busways are available in a wide range of sizes and types for lighting loads and such power loads as cranes, hoists, portable tools and high-cycle tools.

GRAPHICAL ELECTRICAL SYMBOLS FOR ARCHITECTURAL PLANS

GENERAL OUTLETS

Ceiling Wall

- Outlet
- Blanked Outlet
- Drop Cord
- Electric Outlet; for use only when circle used alone might be confused with columns, plumbing symbols, etc
- Fan Outlet
- Junction Box
- Lamp Holder
- Lamp Holder with Pull Switch
- Pull Switch
- Outlet for Vapor Discharge Lamp
- Exit Light Outlet
- Clock Outlet (Specify Voltage)

CONVENIENCE OUTLETS

- Duplex Convenience Outlet
- Convenience Outlet other than Duplex 1=Single, 3=Triplex, etc
- Weatherproof Convenience Outlet
- Range Outlet
- Switch and Convenience Outlet
- Radio and Convenience Outlet
- Special Purpose Outlet (Des. in Spec.)
- Floor Outlet

SWITCH OUTLETS

- S Single Pole Switch
- S_2 Double Pole Switch
- S_3 Three Way Switch
- S_4 Four Way Switch
- S_D Automatic Door Switch
- S_E Electrolier Switch
- S_K Key Operated Switch
- S_P Switch and Pilot Lamp
- S_{CB} Circuit Breaker
- S_{WCB} Weatherproof Circuit Breaker
- S_{MC} Momentary Contact Switch
- S_{RC} Remote Control Switch
- S_{WP} Weatherproof Switch
- S_F Fused Switch
- S_{WF} Weatherproof Fused Switch

SPECIAL OUTLETS

$S_{a,b,c,etc}$

Any standard symbol as given above with the addition of a lower case subscript letter may be used to designate some special variation of standard equipment of particular interest in a specific set of architectural plans.

When used they must be listed in the Key of Symbols on each drawing and if necessary further described in the specifications.

PANELS, CIRCUITS, AND MISCELLANEOUS

- Lighting Panel
- Power Panel
- Branch Circuit; Concealed in Ceiling or Wall
- Branch Circuit; Concealed in Floor
- Branch Circuit; Exposed
- Home Run to Panel Board. Indicate number of circuits by number of arrows.
  Note: Any circuit without further designation indicates a two-wire circuit. For a greater number of wires indicate as follows: —///— (3 wires) #### (4 wires), etc.
- Feeders. Note: Use heavy lines and designate by number corresponding to listing in Feeder Schedule.
- Underfloor Duct and Junction Box. Triple System.
  Note: For double or single systems eliminate one or two lines. This symbol is equally adaptable to auxiliary system layouts.
- Generator
- Motor
- Instrument
- Power Transformer (Or draw to scale.)
- Controller
- Isolating Switch

AUXILIARY SYSTEMS

- Pushbutton
- Buzzer
- Bell
- Annunciator
- Outside Telephone
- Interconnecting Telephone
- Telephone Switchboard
- Bell-Ringing Transformer
- D Electric Door Opener
- F Fire Alarm Bell
- F Fire Alarm Station
- City Fire Alarm Station
- FA Fire Alarm Central Station
- FS Automatic Fire Alarm Device
- W Watchman's Station
- W Watchman's Central Station
- H Horn
- N Nurse's Signal Plug
- M Maid's Signal Plug
- R Radio Outlet
- SC Signal Central Station
- Interconnection Box
- Battery
- Auxiliary System Circuits
  Note: Any line without further designation indicates a 2-wire system. For a greater number of wires designate with numerals in manner similar to —-— 12-No. 18W-3/4"C., or designate by number corresponding to listing in Schedule.
- a,b,c Special Auxiliary Outlets.
  Subscript letters refer to notes on plans or detailed description in specifications.

Number of Circuits

The number of branch circuits required to handle the general lighting load is based on the total load to be served, the layout of the lighting system and outlets, the amount of load to be placed on each circuit and the capacity of the circuits to be used. According to the code, the number of circuits shall be not less than that determined from the total computed load and the capacity of the circuits to be used. However, where a branch circuit load will be in operation for long periods—such as general illumination in large office areas, offices, schools, hospitals, industrial plants and the like—the total load on each branch circuit shall not exceed 80% of the rating of the circuit. Although these code recommendations provide safety in the system, good design practice dictates even more limited loading of lighting branch circuits to assure minimum voltage drop, efficient operation and spare capacity for increases in load. Loading of circuits to half capacity is a widely used and highly recommended practice.

When fluorescent or mercury vapor lighting is used on branch circuits, the presence of the inductive effect of the ballast or transformer creates a power factor consideration. Determination of the load in such cases must be based on the total of the ampere rating of the units and not on the wattage of the lamps.

In many cases, determination of required branch circuit capacity has to be made without a detailed lighting layout. Then, the number and types of circuits for general lighting may be based on a total wattage load obtained from a watts-per-square-foot table of "Standard Loads for Illumination in Commercial and Public Buildings" or "Loads for General Illumination from Overhead Sources in Industrial Occupancies" (see table in "DISTRIBUTION" section). Of course, known loads which exceed the loading indicated in these tables take precedence in design calculations.

In commercial and institutional buildings, layout of the lighting outlets must conform to the general lighting plan, taking into consideration the required lighting result and the type and size of luminaires to be used. Location of lighting outlets will be determined accordingly. In general, spacing between adjacent outlets should not exceed the floor-to-ceiling distance. In industrial buildings, location and spacing of outlets will vary with the work being done, the size and architectural features of the interior. Depending upon these factors, more or less of the lighting load will be general lighting rather than local lighting. Again, location of lighting outlets must correspond to the lighting plan.

Basic Data

The framework of lighting and appliance branch circuit design is given in Article 210 of the code. As set forth in section 2101, the scope of this article covers "branch circuits supplying lighting or appliance loads or combinations of such loads. If motors, or motor-operated appliances, are connected to any circuit supplying lighting or other appliance loads, the provisions of both this article and Article 430 shall apply. Article 430 shall apply if branch circuit supplies only motor loads." Although Article 210 gives the general overall provisions for branch circuits, additional requirements and recommendations on branch circuits are given in other articles of the code covering specific equipment, loads and systems.

A branch circuit is rated according to the setting or rating of the overcurrent device used to protect the circuit. Branch circuits with more than one outlet may be rated at 15, 20, 30 or 50 amps. Although the conductors used in a circuit may have a current carrying capacity higher than the rating of the protective device, the rating of the circuit is determined by the rating of the protective device.

Circuit Voltage

Voltage limitations for branch circuits are presented in section 2113. In general, branch circuits serving lampholders, fixtures or receptacles of the standard 15-amp or less rating are limited to a maximum voltage rating of 150 volts to ground. Exceptions to this rule are as follows:

a. In industrial occupancies, branch circuits supplying only mogul-base, screw-shell lampholders or other approved types of lampholders may be operated above 150 volts to ground, but not above 300

BRANCH CIRCUIT DATA
For
Type R, RH, RW, RU, RUW, T and TW
Conductors in Raceway or Cable

Circuit Rating	15 Amp	20 Amp	30 Amp	50 Amp
Minimum Size of Circuit Wires	#12	#12	#10	#6
Overcurrent Protection	15 Amp	20 Amp	30 Amp	50 Amp
Outlet Devices:				
Lampholders	Any Type	Any Type	Heavy Duty	Heavy Duty
Receptacle Rating	15 Amp	20 Amp	30 Amp	50 Amp
Maximum Load	15 Amp	20 Amp	30 Amp	50 Amp
Permissible load for circuits with two or more outlets. (Individual branch circuits may supply any loads.)	Lighting units and/or appliances. No portable appliance shall exceed 80% of circuit rating. Total rating of fixed appliances shall not exceed 50% of circuit rating if lighting units or portable appliances are also supplied by the circuit.		Fixed lighting units in other than dwelling occupancies; or appliances in any occupancy. No portable appliance shall exceed 24 amps.	Fixed lighting units in other than dwelling occupancies; or fixed cooking appliances; or fixed range and water heater; or infrared-lamp industrial heating appliances.

WIRES USED FOR BRANCH CIRCUITS

TYPE	CONSTRUCTION	APPLICATION
R	Single rubber-insulated conductor with braided cotton covering, rated at 60 C maximum operating temperature.	For general use in dry locations.
RH	Similar to type R, but has heat-resistant rubber insulation, rated for 75 C operation.	For general use in dry locations. Has higher current carrying capacity than type R.
RW	Similar to type R, but has moisture-resistant rubber insulation, rated for 60 C operation.	For general use in dry or wet locations. Has same current capacity as type R.
RH-RW	Combines types RH and RW; has heat- and moisture-resistant rubber insulation, rated 75 C in dry locations and 60 C in wet locations.	For general use in dry or wet locations. In dry locations, has current capacity of type RH; in wet locations, has current capacity of type RW.
RHW	Similar to RH-RW, rated for 75 C operation in all installations.	For general use in dry or wet locations. Has current capacity of type RH.
TW	Single plastic-insulated (polyvinyl chloride) conductor; has high heat, moisture and corrosion resistance, rated for 60 C operation.	For general use in dry or wet locations. Has smaller cross-sectional area than type R, but is held to the same conduit occupancy. Has same current capacity as type R.
RU, RUH and RUW	Latex rubber equivalents of types R, RH and RW. Temperature ratings correspond.	Applications correspond to types R, RH and RW.

volts to ground, provided the lighting units are mounted at least 8 ft above the floor and do not have switch control within the unit itself.

b. In industrial, commercial and institutional occupancies, branch circuits serving only ballasts for mercury vapor or fluorescent lamps may be operated above 150 to ground, but not above 300 volts to ground, provided the ballasts are in permanently installed fixtures mounted at least 8 ft above the floor and the fixtures do not have manual switch control as an integral part of them.

c. Certain electric railway applications utilize higher circuit voltages.

d. Infrared lamp industrial heating appliances may be used on higher circuit voltages as allowed in section 4237 of the code. The requirements for circuits serving electric heating devices are given in a later section of this report.

"In dwelling occupancies, the voltage between conductors supplying lampholders of the screw-shell type, receptacles, or appliances shall not exceed 150 volts, except that the voltage between conductors supplying only (a) permanently connected appliances, or (b) portable appliances of more than 1,380 watts, or (c) portable motor-operated appliances of one-quarter horsepower or greater rating may exceed 150 volts."

Circuit Loading

Code limitations on the use of branch circuits with two or more outlets are as follows:

15- and 20-amp branch circuits may serve lighting units and/or appliances. The rating of any one portable appliance shall not exceed 80% of the branch circuit rating. Although fixed appliances may be connected to a circuit serving lighting units or portable appliances, provided the total rating of the fixed appliances does not exceed 50% of the circuit rating, good design provides separate circuits for individual fixed appliances. In commercial and industrial buildings, separate circuits should be provided for lighting and separate circuits for convenience receptacles.

30-amp branch circuits may serve fixed lighting units in other than dwelling occupancies or appliances in any occupancy. Any individual appliance which draws more than 24 amps may not be connected to this type of circuit.

50-amp branch circuits may serve fixed lighting units in other than dwelling occupancies, fixed cooking appliances, fixed range and water heater, or infrared lamp industrial heating appliances.

Requirements for branch circuits for grouped loads are covered in Section 2127 of the National Electrical Code. As indicated, branch circuits for lighting are limited to a maximum loading of 50 amps. Other limitations for general-purpose lighting and appliance circuits are presented in Article 210 of the code. Individual branch circuits may supply any loads. Excepting motors, this means that an individual piece of equipment may be connected to a branch circuit which has sufficient carrying capacity in its conductors, is protected against current in excess of the capacity of the conductors and in excess of 150% of the rating of the individual load, and supplies only the single outlet for the load device.

Design of lighting and appliance branch circuits for dwelling type occupancies (hotels and apartment houses) should be based on a minimum provision of one 20-amp, 2-wire, 120-volt circuit for each 500 sq ft of floor area. The number of circuits determined in this way will handle general illumination and convenience receptacles spaced every 12 linear feet around the perimeters of the living room, bedrooms, parlor, library, den, sun room and recreation room. At least one 3-wire, 20-amp, 120/240- or 120/208-volt circuit shall be provided to serve the small appliance load in the kitchen, laundry, pantry, dining room and breakfast room of dwelling occupancies. This 3-wire circuit is split-wired to convenience receptacle outlets in these areas and must have no other outlets. Of course, two 2-wire, 20-amp, 120-volt circuits are equivalent to the 3-wire circuit and could be used.

In apartment houses and hotel rooms, all receptacle outlets rated 15-amp or less (excepting air conditioning outlets and those outlets on the kitchen appliance circuits) are considered as outlets for general illumination and no additional load has to be included for such outlets. In other occupancies, circuit capacity must be provided for all receptacle outlets and outlets serving loads separate from general illumination.

For lighting other than general lighting, and for appliances other than motor-operated, circuit capacity for each outlet must be provided as follows:

For each outlet supplying a specific appliance or load device, circuit capacity equal to the amp rating of the appliance or device must be provided.

For each outlet supplying a heavy-duty lampholder, 5 amps of circuit capacity must be allowed.

For each other outlet, at least 1.5 amps must be allowed.

When a circuit supplies only motor operated devices, the provisions of Article 430 of the code must be taken into consideration.

The above minimum load allowances for receptacle outlets and outlets for local lighting and appliances are modified for certain applications:

Table 29 in Chapter 10 of the code establishes the basis for computing the required branch circuit capacity for electric cooking appliances. For show-window lighting, 200 watts of load can be allowed for each linear foot of show-window, measured along its base (instead of an allowance of the specified load per outlet).

A capacity of 1.5 amps must be allowed for each 5 ft or fraction thereof of each separate and continuous length of fixed multi-outlet assemblies. Each such length is considered as one outlet of 1.5-amp capacity. In those places where it is likely that a number of appliances will be used simultaneously, each one foot or fraction thereof is considered as an outlet and requires a load allowance of 1.5-amp. Allowances for multi-outlet assemblies do not apply to dwellings or guest rooms in hotels.

Conductors and Ratings

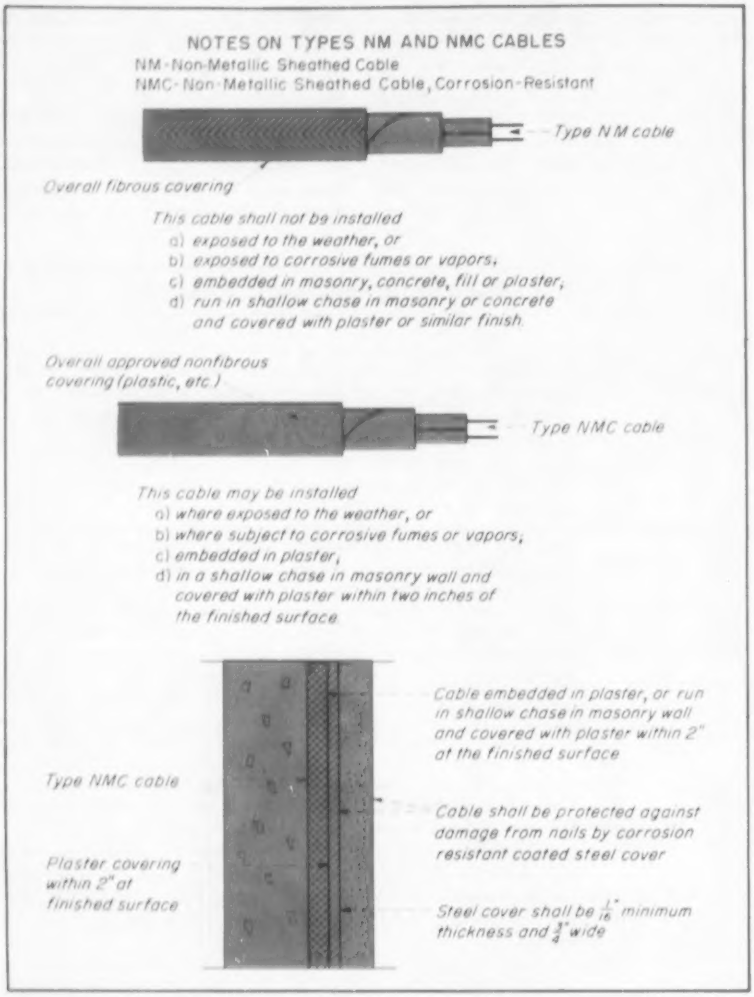
Although the code establishes No. 14 as the minimum size of wire to be used for branch circuit wiring, good design practice dictates the use of No. 12 as the minimum size, protected at either 15 or 20 amps. For electric ranges of 8¾ kw or more, No. 8 is the code minimum size, but No. 6 is the recommended size to be used. In a 3-wire single-phase branch circuit to an electric range, the neutral may be sized on the basis of 70% of the current-carrying capacity of the ungrounded conductors, although it may not be smaller than No. 10.

According to the code, the rating or setting of overcurrent device in any branch circuit shall not exceed the current-carrying capacity of the circuit conductor. If a circuit serves only one appliance rated at 10 amps or more, the rating of the overcurrent device must not exceed 150% of appliance rating.

Specific limitations are placed on outlet devices for branch circuits. Lampholders must not have a rating lower than the load to be served; and lampholders connected to circuits rated over 20 amps must be heavy-duty type. Receptacles must have ratings at least equal to the load. On circuits having two or

CABLES USED FOR BRANCH CIRCUITS

TYPE	*CONSTRUCTION*	*APPLICATION*
AC and ACT (National Electrical Code, Article 334)	Flexible metallic armored cables. Rubber (AC) or thermoplastic (ACT) insulated conductors in wound and interlocked steel armor covering, with bonding strip under armor.	For general interior wiring, except in moist areas or in block walls below grade.
ACV (NEC Art. 334)	Flexible metallic armored cable with varnished cambric insulated conductors.	For use exposed in dry locations in industrial areas.
ACL (NEC Art. 334)	Flexible metallic armored cable with lead-covered conductors.	For use where exposed to weather or moisture, for underground runs, for embedding in masonry or concrete or where exposed to oil, gasoline or other deteriorating agents.
NM (NEC Art. 336)	Non-metallic sheathed cable. Rubber or thermoplastic insulated conductors, with or without separate grounding conductor, covered by heavy paper wrapping and strong braid.	For interior wiring, exposed or concealed in dry locations. Must not be used exposed to corrosive fumes or vapors or embedded in concrete, masonry, fill or plaster.
NMC (NEC Art. 336)	Same as type NM cable except that it has a corrosion-resistant outer covering of non-fibrous material, such as neoprene or thermoplastic.	For interior wiring, in same ways as type NM, except that it may be embedded in plaster or run in chase if a 1/16 in. steel plate is provided for protection against nails.
MI (NEC Art. 330)	Mineral-insulated, metal-sheathed cable. Conductors insulated by highly compressed refractory mineral material and enclosed in liquid-tight and gas-tight flexible metallic tube sheathing.	For exposed or concealed use in dry or wet locations, under plastic, embedded in plastic finish on brick or other masonry, exposed to weather or moisture, underground runs, embedded in masonry, concrete or fill, in buildings in course of construction, or exposed to oil, gasoline or other conditions not having a deteriorating effect on the metal sheath.
UF (NEC Art. 339)	Underground feeder and branch circuit cable. Conductors may be plastic or rubber insulated, with an outer covering which is flame-retardant, moisture-resistant, fungus-resistant, corrosion-resistant and suitable for direct burial in the earth.	For use underground, directly buried in the earth, as branch circuit cable. Multi-conductor type UF cable may be used as NMC cable, and may be used in wet locations.



more outlets, receptacles shall be rated as follows:

On 15-amp circuits—not over 15-amp rating.

On 20-amp circuits—15- or 20-amp rating.

On 30-amp circuits—20- or 30-amp rating.

On 50-amp circuits—50-amp rating.

The code notes the possibility of using both ac and dc energy in a single building and requires the use of attachment plug caps which are not interchangeable between ac and dc receptacles.

All of the foregoing constitutes minimum standards for branch circuits. Actual design of circuiting begins with these requirements.

Design Approach

Design standards for lighting and appliance circuits are aimed at providing convenience, flexibility, operating efficiency and reliability in using the available energy. To assure all the advantages of sufficient circuit capacity plus spare capacity for load growth, modern design practice dictates separation of loads into known, approximated and unknown loads. As a result, general illumination is a known load—whether derived from a detailed lighting layout, or developed from a watts-per-square-foot calculation. Number, rating and layout of outlets for general illumination can easily and accurately be apportioned among a number of branch circuits. Such circuits can be carefully loaded with due regard to voltage drop, operating cycle, possible increase in lighting level in the future and required control.

Depending upon the type of occupancy and how the interior is to be laid out from a work standpoint, outlets for local and/or special lighting units represent approximated loads. Such outlets are included in the overall lighting design, either as fixed unit loads or estimated plug-in loads. Outlets—either lampholders or plug receptacles—for such lighting units may be connected to general lighting circuits, provided with separate circuiting or included in circuits allowed for plug receptacles.

Design of branch circuits for plug receptacles requires careful determination of particular requirements. The type and size of occupancy and nature of the work performed there will indicate the best manner of handling plug-connected loads. For known appliances, individual or multi-outlet branch circuits should be used, depending on the size of the load represented. Automatic appliances should always be provided with separate circuits to isolate such appliances from the effects of faults or other disturbances in other load devices. Fans or heaters might be individually fed by branch circuits, grouped on their own branch circuits or connected to receptacles on general lighting circuits. Of course, the number of plug-in appliances in a particular area will greatly affect the circuiting. In general, plug-in devices should be supplied from receptacles on circuits other than general lighting circuits. In this way, the relative loading of circuits can be kept under better control, and spare capacity can be more realistically allowed. Provision of miscellaneous plug receptacles should be made to meet anticipated need for such receptacles.

Circuit Standards

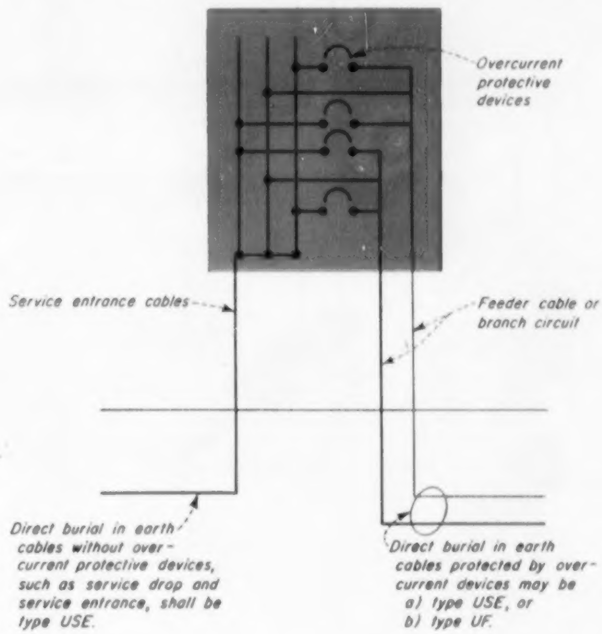
Summarizing the recommendations made in foregoing discussion of code sections, the following are important standards for modern branch circuit design. Of course, in many cases, practical considerations such as size of area or type of load devices will require deviation from the letter of these standards. In such cases, however, the designer must use his judgment in assuring adequacy and other desired characteristics of the circuits. For instance, a circuit having only exit lights has little need for spare capacity. General standards for the majority of applications, however, are as follows:

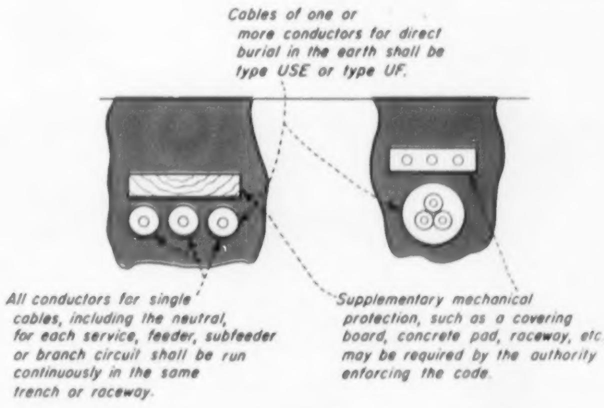
- Separate branch circuits should

be provided for general lighting, for automatic appliances, for fixed appliances and for plug receptacles. Generally, each automatic or fixed appliance should be served by an individual circuit.

- Branch circuits with more than one outlet supplying general lighting should not be loaded in excess of 50% of their carrying capacity.
- Branch circuits with more than one outlet supplying plug receptacles should not be loaded in excess of 50% of their carrying capacity.
- Branch circuits with more than one outlet supplying heavy-duty lampholders should not be loaded in excess of 50% of their carrying capacity.
- Individual branch circuits should have spare capacity 20% in excess of their loads.
- At least one spare circuit should be allowed for each five circuits in use.
- The smallest wire size used in branch circuiting should be No. 12.
- Size of wire to be used in a branch circuit home run should be at least one size larger than that computed from the loading when the distance from the overcurrent protective device to the first outlet is over 50 ft.
- When the distance from the overcurrent protective device to the first plug outlet on a receptacle circuit is over 100 ft, the size of the circuit home run should not be less than No. 10 and may be larger depending upon the rating of the particular circuit, the actual distance, voltage drop and the load conditions.
- Home runs on lighting circuits should be limited to a maximum of 100 ft, unless the load on the circuit is so small that voltage drop between the overcurrent protective device and any outlet is under 1%. Careful layout of panelboard locations and use of sufficient number of panelboards will avoid this problem of long home runs.

NOTES ON TYPE UF CABLE FOR UNDERGROUND CIRCUITS

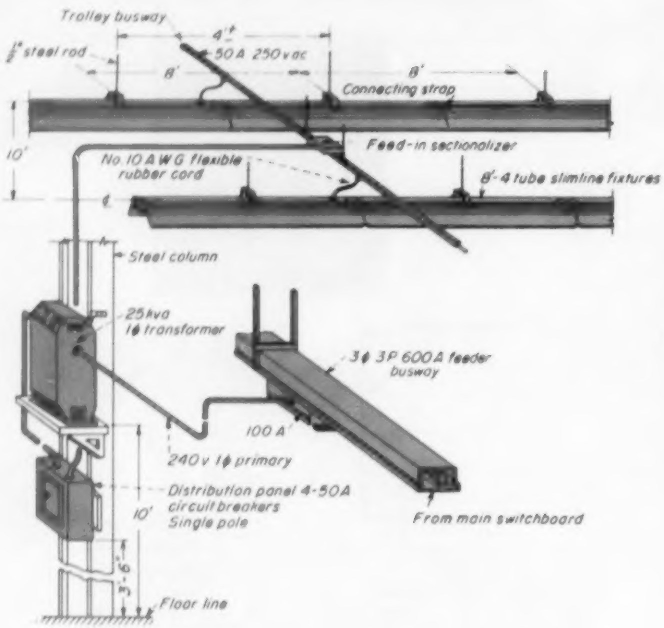




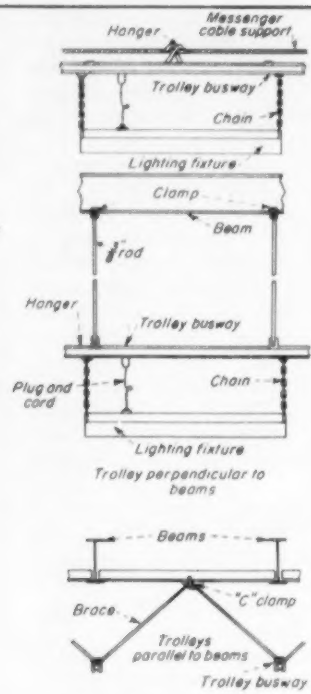
Plug Receptacles

The number of plug outlets connected on a single circuit should be related to the amount of load likely to be connected to any one receptacle in a particular occupancy. When plug-connected loads are known, determination of the proper number of plug outlets is relatively easy. And the number of circuits required in such cases follows directly from the loads and circuit capacities. When plug-connected loads are not known, the type of occupancy will indicate the possible appliances to be provided for. If the possible appliances are relatively heavy-current devices, two or three outlets per circuit might be the maximum number to allow efficient and convenient use of the circuits. If the possible appliances are low-current devices, up to ten plug outlets may be connected on the circuit without the likelihood of overload. Of course, the possible number of appliances to be used in any area will also affect the design of receptacle circuits. When special requirements for receptacle circuits arise after tenants move into an area, the spare circuits in the panelboard and extra capacity in the existing system of raceways or underfloor system will offer solution to the need.

Number of plug outlets required for different occupancies is not a matter of easy or standard calculation. In office buildings, growing use of business machines dictates heavier load allowances for plug outlets. In separate offices of less than 400 sq ft area, at least one

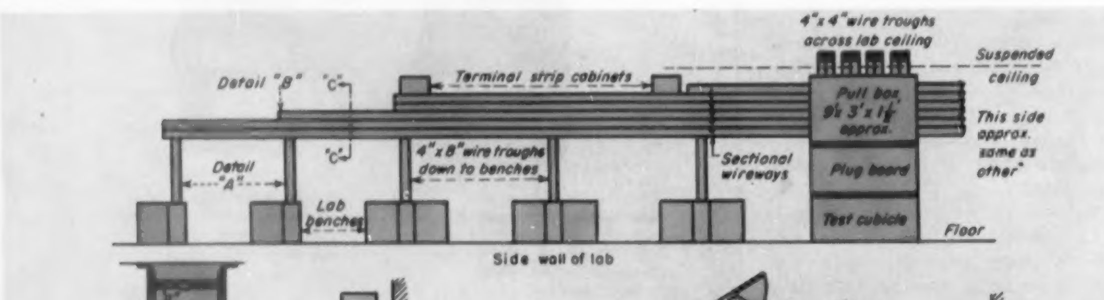


ONE TYPE OF TROLLEY BUSWAY DESIGN



SUSPENSION DETAILS FOR TROLLEY BUSWAY

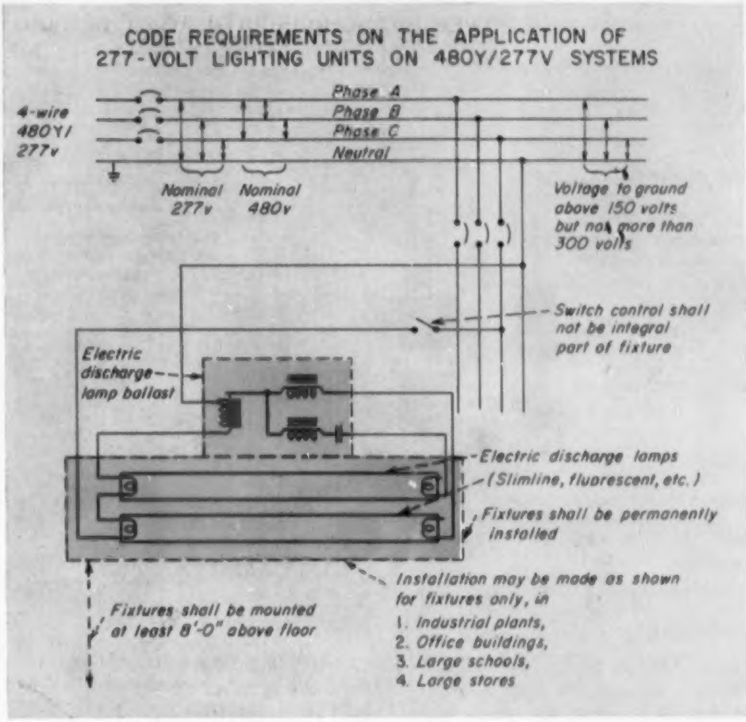
TROLLEY BUSWAY serves as lighting branch circuit, fed from four 50-amp CB's in lighting panel. The panel is supplied from transformer secondary, powered from a tap to a busway feeder or subfeeder. The lighting fixtures are suspended from the trolley busway, from beams or from the ceiling. The trolley busway is supported from ceiling, beams, messenger cable, or braces supported from the beams.

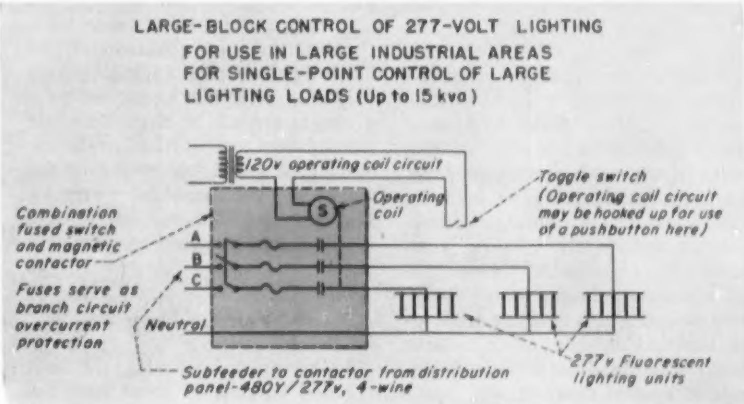


WIREWAYS of standard or special design offer simple and effective routing of multi-wire or complex branch circuit or control conductors. In many cases where access to wiring is required or desirable for changing of circuiting, specially fabricated sheet steel wire enclosures with removable panels offer distinct advantages over any other type of raceway. This is particularly true for motor and control circuits.

plug outlet should be allowed for each 20 linear feet of wall space. In each office area of over 400 sq ft, five plug outlets should be allowed for the first 400 sq ft of floor area and two plug outlets for each additional 400 sq ft of floor area or fraction thereof. The number of outlets obtained in this way should be evenly distributed throughout the area. In schoolrooms, common practice has been to provide one plug outlet on the front wall of the room and one on the rear wall. In stores, at least one plug outlet should be provided for each 400 sq ft of floor area or major fraction thereof. Plug outlets for industrial areas should be provided on the basis of particular conditions in each case.

Branch circuit design must include provision of control of the circuits. Circuits supplying only plug outlets need not be controlled locally, although such control is often desirable and recommended. Control of branch circuits at the panelboard is a common and satisfactory practice in many occupancies. But in most occupancies, local control should be provided for convenience and economy of operation. Switching may be done at the circuit voltage or by low-voltage relays.





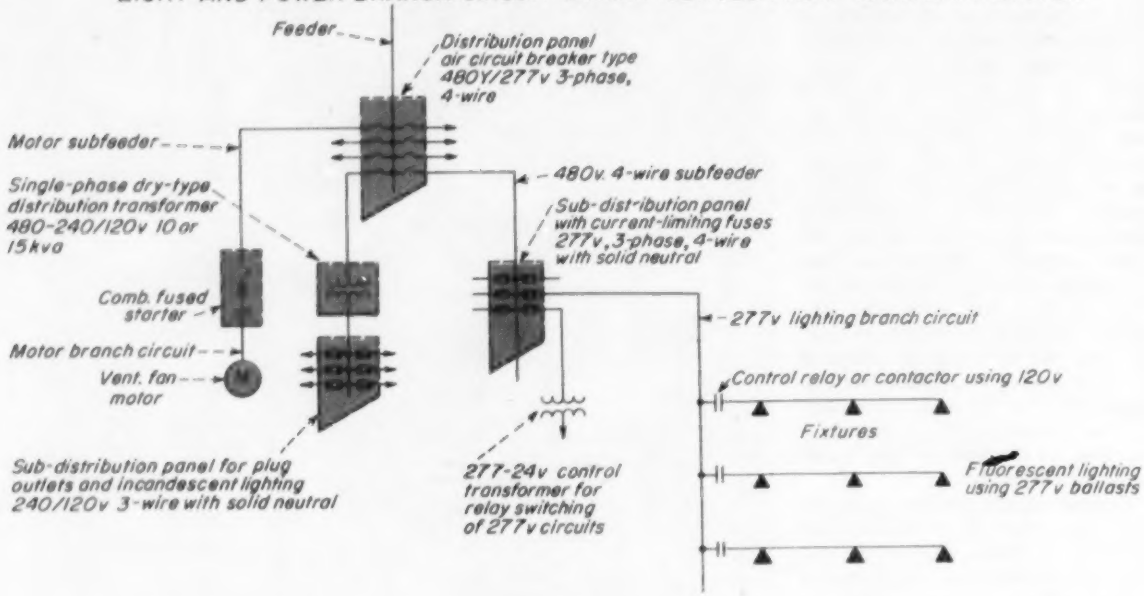
Layout on Plans

Actual design procedure for lighting and appliance branch circuits involves working on a set of plans for the building. Such plans are usually available or can be made. The design work consists of using the foregoing information and whatever other data is known in laying out the outlets, circuit runs and control legs. Of course, this step depends upon a decision having been made as to the general type of distribution and characteristics and voltage of the feeders from which the branch circuits will be supplied. The extent of plans required for notating the electrical design will depend upon the relative complexity and amount of the particular circuitry and the type of occupancy involved.

The first step in circuit design is to indicate locations of general lighting outlets on floor plans. This layout of general lighting outlets is part of overall lighting design. As follow-up to this part of the work, the wattage of each outlet is determined, the total load is determined and the number of circuits is selected. Then the local or special lighting outlets are indicated. These include: corridor lights, exit lights, entrance lights, washroom lights, closet lights, stockroom lights, emergency lights and/or other known lighting outlet requirements. Of course, in the design of many commercial and industrial buildings, the specifics of lighting requirements may not be known until after it is known what type of work will be performed and tenants decide upon their working layout. In such cases, provision of sufficient capacity and circuits in the panelboard is the initial limit of circuit design work.

After laying out lighting outlets, the next usual step is to indicate convenience and special receptacle outlets on the plans. Depending upon the occupancy, receptacle circuits may be run in conduit to wall-mounted or column-mounted outlet boxes, fed up from the floor slab or down from the ceiling, or the circuits may be run in underfloor raceway or a cellular metal floor system. These latter are the common ways of handling receptacle circuits in modern office and other commercial areas. When receptacles are wall-mounted they should be evenly spaced in accordance with the limit of maximum spacing between adjacent outlets. The underfloor systems offer more uniform layout of receptacles throughout

LIGHT AND POWER BRANCH CIRCUIT LAYOUT SERVED FROM 480Y/277V SYSTEM



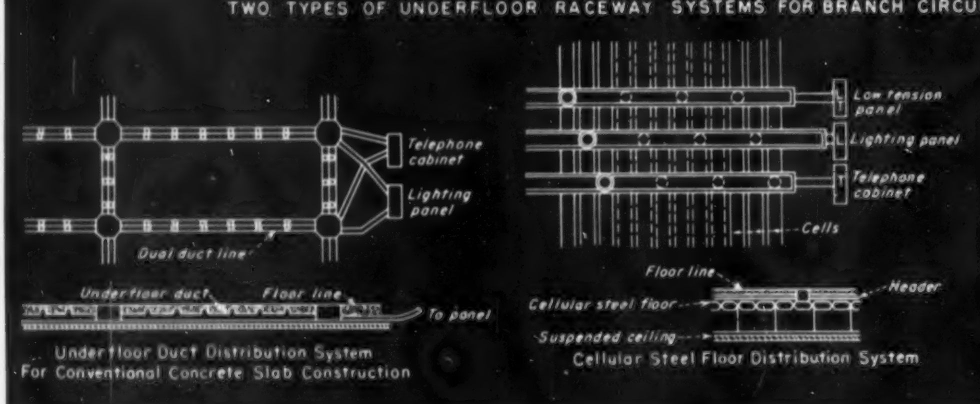
an area. Of course, the general construction of the building—architectural features of the area, type of floor slab construction—will affect the way the circuits are run and the locations of outlets. On the basis of careful selection of the number and types of convenience receptacles for general loads and special receptacles for known loads, layout of the outlets must conform to any known locations of load devices, allowing even spacing of convenience outlets for general (unknown) plug-connected loads. Special attention should be given to receptacle circuits serving individual loads. Fan and clock outlets should also be determined on the basis of special analysis.

From the indications of outlets and corresponding wattages on the plans, the number of circuits is the next determination. As discussed previously, circuiting to these outlets may be done in many ways. Combinations of general lighting, local lighting and appliance loads or motor loads can be connected to a single circuit if particular conditions require. But separate circuiting of load types wherever possible is recommended practice. Makeup and loading of circuits should follow previous recommendations.

Voltage Drop

In laying out circuits, the loading and lengths of home runs and runs between outlets must be related to voltage drop and the need for spare capacity in the circuit for possible future increases in load. Each lamp, appliance or other utilization device on the circuit was designed for best performance at a particular operating voltage. Although such devices will operate at voltages on either side of the design value, there will be generally adverse effects due to operation at voltages lower than the specified value. A 1% drop in voltage to an incandescent lamp produces about a 3% decrease in light output; a 10% voltage drop will decrease the output about 30%. In heating devices of the resistance element type, voltage drop has a similar effect on heat output. In motor operated appliances, low voltage to

TWO TYPES OF UNDERFLOOR RACEWAY SYSTEMS FOR BRANCH CIRCUITS



Underfloor Duct Distribution System
For Conventional Concrete Slab Construction

Cellular Steel Floor Distribution System

Size Awg	No. of Wires in 40 Percent of Header Duct	
	Types R, RH, RW	Types T, TW, RU
14	109	185
12	90	145
10	54	112
8	33	61
6	20	31
4	16	23
3	14	20
2	12	17
1	9	12
0	8	11

AVERAGE CIRCUIT LENGTHS (FEET) FOR 1% VOLTAGE DROP

TABLE I. SINGLE-PHASE AC LOADS
115/230 Volts, 60 Cycles, 100% PF

AMPERE LOAD	WIRE SIZE—CIRCULAR MILS					WIRE SIZE—B & S or A.W.G.									
	500	400	350	300	250	4/0	3/0	2/0	1/0	1	2	3	4	6	8
40	1106	898	788	669	558	475	378	299	239	188	150	119	94	59	38
50	885	719	630	535	447	380	303	240	191	150	120	91	75	47	30
60	737	599	525	446	372	317	252	200	159	125	100	79	62	39	
70	632	513	450	382	319	271	216	171	136	107	86	68	53	34	
80	553	449	394	334	279	238	189	150	119	94	75	59	47		
90	491	399	350	297	248	211	168	133	106	83	67	53	42		
100	442	359	315	267	223	190	151	120	95	75	60	47			
110	402	327	286	243	203	173	138	109	87	68	55				
120	369	299	263	223	186	158	126	100	79	63					
130	340	276	242	206	172	146	116	92	73	58					
140	316	257	225	191	159	136	108	86	68						
150	295	240	210	178	149	127	101	80	64						
160	276	225	197	167	140	119	95	75	60						
170	260	211	185	157	131	112	89	70							
180	246	200	175	148	124	106	84	66							
190	233	189	166	140	117	100	80								
200	221	180	157	134	112	95	76								
210	211	171	150	127	106	90									
220	201	163	143	122	101	86									
230	192	156	137	116	97	83									
240	184	150	131	111	93										
250	177	144	126	107	89										
260	170	138	121	103	80										
270	164	133	117	99											
280	158	128	112	96											
290	152	124	109	92											
300	147	120	105												
310	143	116	102												
320	138	112													
330	134	109													
340	130	106													

Calculations based on copper resistance of 12.5 ohms per CM-ft at 50C (122F).

Reactance and impedance losses calculated for each wire.

Conductors closely grouped in metallic conduit.

TABLE II. 3-PHASE DELTA AC LOADS
230 Volts, 60 Cycles, 85% PF

AMPERE LOAD	WIRE SIZE—CIRCULAR MILS					WIRE SIZE—B & S or A.W.G.									
	500	400	350	300	250	4/0	3/0	2/0	1/0	1	2	3	4	6	8
40	710	625	584	530	475	429	364	303	253	208	173	139	113	75	49
50	568	500	467	424	380	343	291	242	203	167	139	111	90	60	39
60	473	417	389	353	317	286	243	202	169	139	115	93	75	50	
70	406	357	333	303	271	245	208	173	145	119	99	79	64	43	
80	355	312	292	265	238	214	182	151	127	104	87	69	56		
90	316	278	259	235	211	191	162	134	113	93	77	62	45		
100	284	250	233	212	190	172	146	121	101	83	69	55			
110	258	227	212	193	173	156	132	110	92	76	63				
120	237	208	195	177	158	143	121	101	84	69	58				
130	218	192	180	163	146	132	112	93	78	64					
140	203	179	167	151	136	123	104	86	72						
150	189	168	156	141	127	114	97	81	67						
160	177	156	146	132	119	107	91	76							
170	167	147	137	125	112	101	86	71							
180	158	139	130	118	106	95	81	67							
190	149	132	123	112	100	90	77								
200	142	125	117	106	95	86	73								
210	135	119	111	101	90	82									
220	129	114	106	96	86	78									
230	123	109	101	92	83	75									
240	118	104	97	88	79										
250	114	100	93	85	76										
260	109	96	90	81	73										
270	105	93	86	78											
280	101	89	83	76											
290	98	86	80	73											
300	95	83	78												
310	92	81	75												
320	89	78													
330	86	76													
340	83	73													
350	81														
360	79														
370	77														
380	75														

Calculations based on copper resistance of 12.5 ohms per CM-ft at 50C (122F).

Reactance and impedance losses calculated for each wire.

Conductors closely grouped in metallic conduit.

TABLE III. BALANCED LIGHTING LOADS
3- and 4-Wire, 115 Volts 1% drop from supply cabinet to first outlet supplying permanently connected appliance or fixture.

AMPERES (A), WATTS (W), WITH CONDUIT CONDUCTOR (C), FILLS (F)

MAXIMUM OVERCURRENT CIRCUIT PROTECTION	INTERMITTENT LOADS			CONTINUOUS LOADS		
	100% F 2-3 C	80% F 4-6 C	70% F 7-9 C	100% F 2-3 C	80% F 4-6 C	70% F 7-9 C
15 A	15 A 1725 W	12 A 1380 W	10.5 A 1207 W	12 A 1380 W	9.6 A 1104 W	8.4 Amps. 966 Watts
20 A	20 A 2300 W	16 A 1840 W	14 A 1610 W	16 A 1840 W	12.8 A 1472 W	11.2 A 1288 W

LOADS AND LENGTHS IN FEET FOR 1% DROP ON 3 AND 4 WIRE 115 V. CIRCUITS

AMPERE LOAD	#10 WIRE	#12 WIRE	#14 WIRE
1	946	596	374
2	474	298	188
3	316	198	124
4	236	148	94
5	190	120	76
6	158	100	62
7	136	86	54
8	118	74	46
9	106	66	42
10	94	60	38
11	86	54	34
12	78	50	32
13	72	46	28
14	68	42	26
15	64	40	24
16	60	38	
17	56	36	
18	52	34	
19	50	32	
20	48	30	
21	46		
22	44		
23	42		
24	40		
25	38		
26	36		
27	36		
28	34		
29	32		
30	32		

Calculations based on copper resistance of 13 ohms per CM-ft at 60C (140F).

NOTES:

TABLE I:

Balanced 3-Wire Loads: Drop is 1.15 volts for given length.

2-Wire, 230-Volt Loads: Drop is 2.3 volts for given length.

TABLE II:

For 208-volt, 4-wire "Y" feeders multiply given length by 0.9

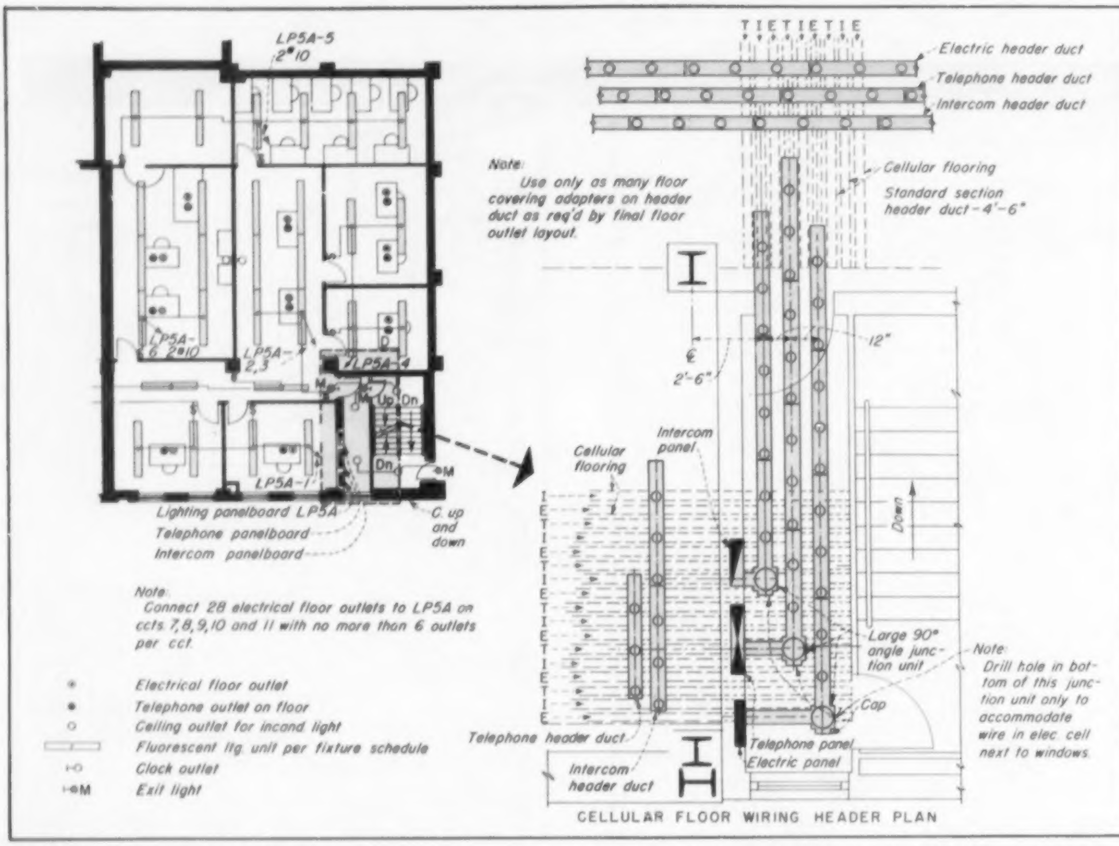
For 230-volt, single-phase feeders multiply given length by 0.85

For 460-volt, 3- or 4-wire feeders multiply given lengths by 2.

For aluminum wire multiply given lengths by 0.7 or use length of copper wire which is 2 sizes smaller than the aluminum size under consideration.

TABLE III:

For 2-phase, 3-wire circuits tapped off a 3-phase, 4-wire "Y" service, multiply given lengths by 0.67.

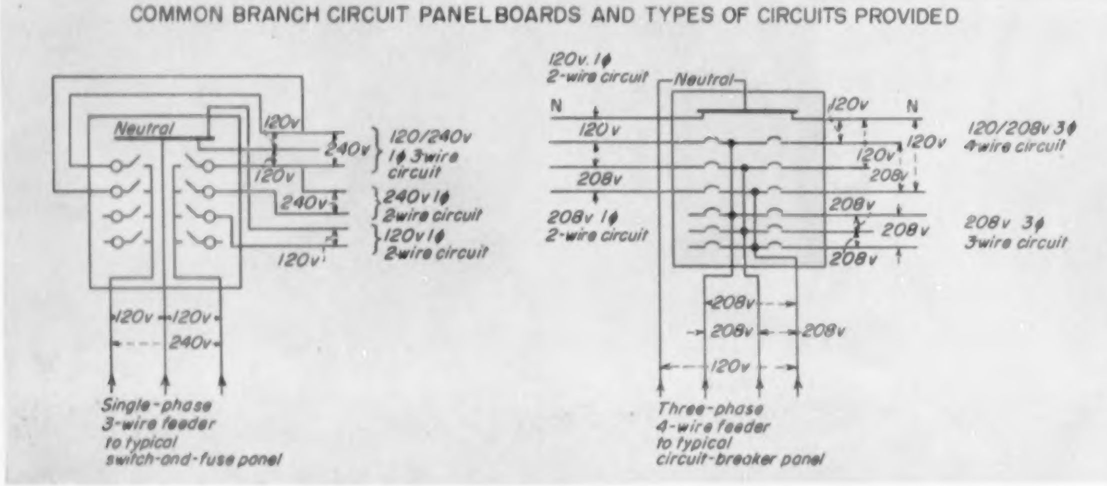


FLOOR PLANS show lighting layouts and locations of panelboards and outlets according to the legend. In the office area shown, a detailed plan of the relation between cellular floor construction and header ducts in various areas is shown. The underfloor wiring detail at right covers the area marked on the portion of the plan at left.

the device will affect the starting and pull-out torque, and the current drawn from the line increases with drop in voltage. Heat rise in the motor windings will be above normal as a result.

Of course, voltage drop in the conductors is due to resistance of the conductors plus, in ac circuits, reactance. And the heat developed by the dissipation of power in the wiring, which itself costs money, deteriorates the conductor insulation. To prevent poor equipment performance and the other bad effects, branch circuit conductors must be sized to keep voltage drop in the circuit under 1%. Although the recommended 50% loading of circuits offers substantial protection against excessive voltage drop, size of conductors for long runs should always be carefully determined to assure that the spare capacity provision has not been removed by the limit of voltage drop. For this reason, when

COMMON BRANCH CIRCUIT PANELBOARDS AND TYPES OF CIRCUITS PROVIDED



the design intent is to use 50% loading to provide spare capacity in the circuit, conductors used in long runs should be sized for voltage drop on the basis of the maximum possible loading.

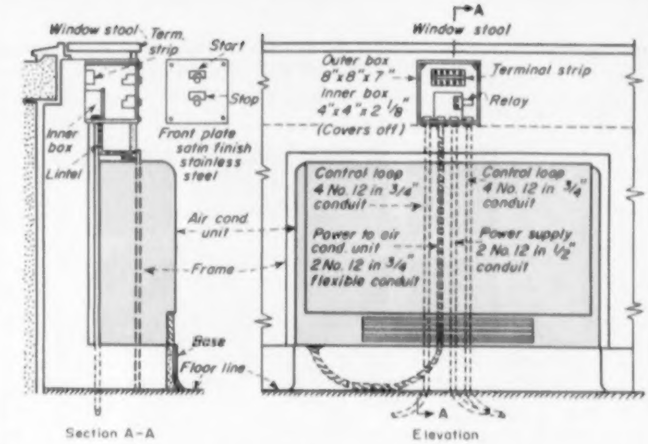
Control

Local switches for load devices and receptacles should be carefully indicated on the plans. The particular requirements for local switching will also have an effect on the number of circuits required. Switching at the panelboard requires a separate circuit for each block of equipment to be switched separately. Such factors as distance from panelboard to lighting fixtures, partitioning of the area of lighting coverage fed from the panelboard, need for three- or four-way switch control will determine the amount of local switching, the amount of panelboard switching and the number of circuits needed. Selection of switch locations on plans should be based on careful analysis of the conditions and requirements of the particular installation. Special control devices such as photoelectric cells, time switches and relays should be carefully designed into the overall branch circuit layout.

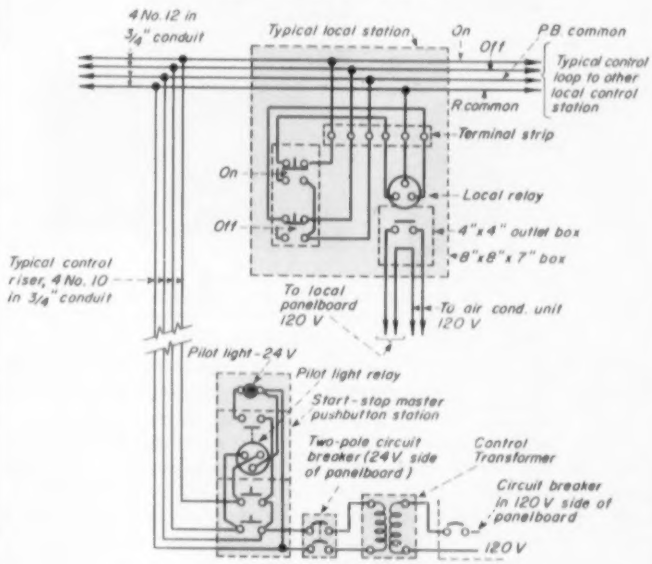
Panelboards

Lighting and appliance branch circuits originate in panelboards in which the overcurrent protective devices for the circuits are mounted. In addition to the protective feature, the panelboard usually contains a means for switching each circuit. Some panelboards have a switch and fuse for each circuit; other panelboards use circuit breakers which provide both protection and switching for the circuits. Of course, overcurrent protection is the only code requirement for branch circuits, and a

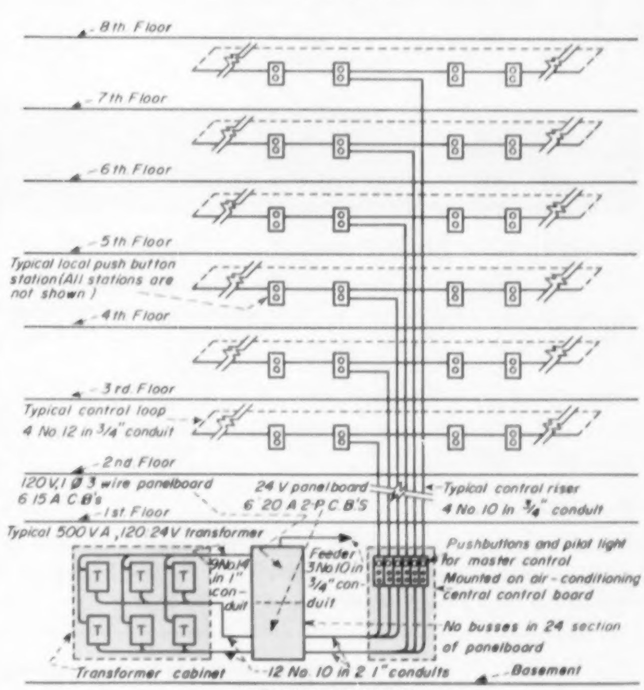
RELAY SWITCHING offers low-voltage, remote-control of branch circuits. At the right, a typical circuit is shown for relay switching of 120-volt branch circuits supplying air conditioning units. The local relay provides switch control for turning the unit "on" or "off" in the office which the unit conditioner serves. The same control can also be exercised from a master pushbutton station in the basement, and all units on all floors are controlled from this point, in addition to having local control. Riser diagram at right shows the layout of the system in the building.



LOCAL CONTROL STATION

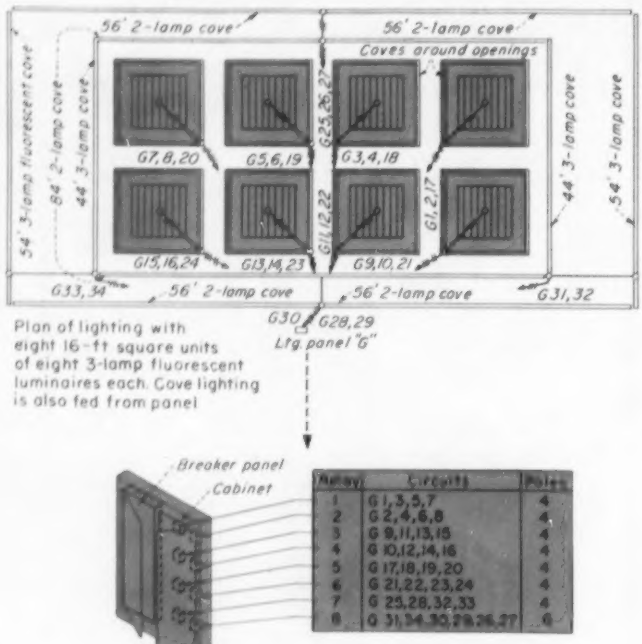


TYPICAL CIRCUIT



RISER DIAGRAM

BRANCH CIRCUIT SWITCHING WITH RELAYS



LIGHTING PANEL "G" CONTAINS BRANCH CB PANEL AND RELAYS CONTROLLING CIRCUIT SWITCHING

panelboard may therefore only contain fuses. In the great majority of cases, however, the advantages of switch or CB control of each circuit at the panelboard dictate against just fuses in the panelboard. In fact, commercial and industrial practice frequently finds the panelboard switches or CB's used as the only control of the circuits. Panelboards may be equipped with a main switch feeding bus in the board. This single switch provides simultaneous disconnect of circuits from the feeder.

To supplement the allowance of spare capacity in the branch circuit design work, spare circuit capacity should be allowed in panelboards. As recommended previously, one spare circuit should be allowed in the panel for each five active circuits. Inasmuch as panelboards are made in multiples of four switch-and-fuse units or circuit breakers, provision of the spare circuits can often be made without using a panelboard larger than required for the active circuits. When spare circuits are provided in flush type panelboards, the required conduit capacity to wire these circuits should be provided to avoid future tearing out of the wall. This may consist of empty conduit runs to the ceiling and floor, terminated in covered outlet boxes, design of spare capacity in other raceways serving the branch circuit load from the panelboard, etc.

General design standards for selection and layout of panelboards are as follows:

No more than 42 branch circuits may originate from a single panelboard.

No branch circuit in a panelboard should run more than 100 feet to the first outlet of the circuit.

All panelboards should be readily accessible.

Panelboards should be placed as near as possible to the center of the load they handle.

If circuit switching from the panelboard is desired, a switch-and-fuse or CB panelboard must be used.

Panelboard locations should be selected to conform as much as possible to the routing of feeders, assuring shortest possible feeder runs and minimum of bends.

Every panelboard must have a rating not less than the minimum feeder capacity required to serve the load as determined from Article 220 of the code.

At least one lighting and appliance branch circuit panelboard should be provided on each active floor of the building.

When lighting and appliance branch circuits, with their control and panelboards, have been laid out, a panelboard schedule should be made up and included in the plans and specifications. This schedule should give some code letter designation to each panelboard—such as L1a for lighting panel "a" on the first floor, L2b for lighting panel "b" on the second floor, etc.—and should tabulate panel locations, number and size of circuits in each panel, type and rating of circuit protective devices, capacity of mains, size and type of main protection and disconnect and any pertinent remarks about each panelboard which might clarify design intent for the installer. It

Calculating Size of Branch Circuit Panelboards for Lighting and Appliance Circuits

Two-Wire DC or Single-Phase:

Total connected load (amperes) = sum of branch loads, as determined above. At least 10 amperes should be allowed for each spare or appliance circuit.

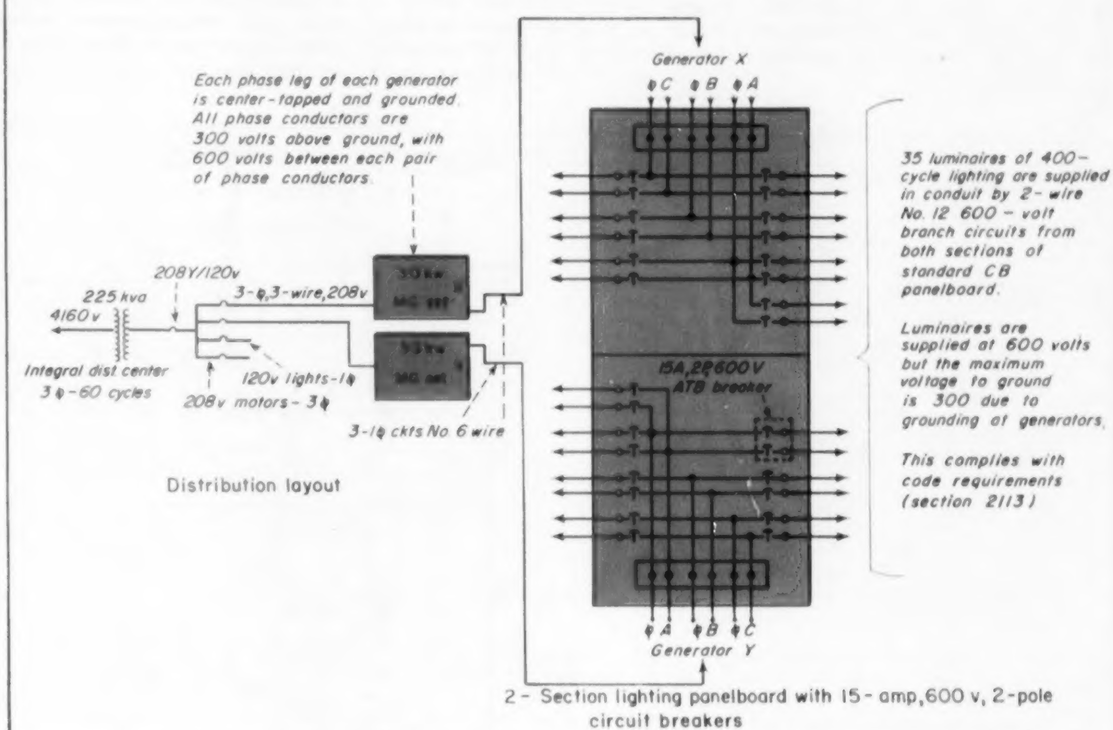
Three-Wire DC or Single-Phase:

Same calculations apply as for Two-Wire Panel, applied separately to each side of panel.

Four-Wire, Three-Phase:

The load on any bus, except the neutral, is computed the same as for a two-wire panel. Usually, the load on each of the four busses is taken as that of the most heavily loaded.

HIGH-FREQUENCY BRANCH CIRCUITS FOR FLUORESCENT LIGHTING ARE DERIVED FROM CONVERTERS AND FED FROM PANELBOARD



TYPICAL DETAILED SCHEDULE OF LIGHTING PANELBOARDS GIVES SELECTION AND INSTALLATION DATA FOR ALL PANELS

LIGHTING PANELBOARD SCHEDULE

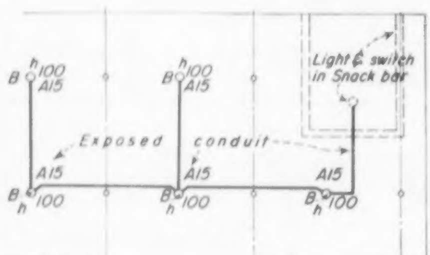
Panel Designation	Location	Equip.	Branch Circuits					Mains		Service			Remarks
			No. Active	No. Spares	Total No.	Poles	Trip Calibr.	Type	Cap	Phase	Feed	Voltg	
LP1A	1st Floor Stair No. 5	Cct. Bkr	25	7	32	SP	20A	Cct. Bkr.	225/125	3	4-300 MCM	120/208	
LP1C	1st Floor Main Stair		27	7	34	SP	20A	"	225/150	3	4-4/0	"	
LP2A	2nd Floor Stair No. 6		29	7	36	SP	20A	"	225/150	3	4-300 MCM	"	
LP2B	2nd Floor Stair No. 1		1 22	1 8	2 30	2P SP	20A 20A	"	225/125	3	4-4/0	"	
LP2C	2nd Floor Main Stair		14	6	20	SP	20A	"	100/70	3	4-4/0	"	
LP3A	3rd Floor Stair No. 6		39	3	42	SP	20A	"	225/175	3	4-350 MCM	"	
LP3B	3rd Floor Stair No. 1		1 20	1 6	2 26	2P SP	20A 20A	"	100/100	3	4-4/0	"	
LP3C	3rd Floor Main Stair		12	4	16	SP	20A	"	100/100	1	–	"	Connect to Existing 3 Wire Feed
LP4A	4th Floor Stair No. 6		18	4	22	SP	20A	"	100/100	3	4-350 MCM	"	
LP4B	4th Floor Stair No. 1		1 13	0 5	1 18	2P SP	20A 20A	"	100/70	3	4-300 MCM	"	
LP5A	5th Floor Stair No. 6		11	9	20	SP	20A	"	100/100	3	4-400 MCM	"	
LP5B	5th Floor Stair No. 1		1 11	1 5	2 16	2P SP	20A 20A	"	100/70	3	4-300 MCM	"	
LP6A	6th Floor Stair No. 6		14	8	22	SP	20A	"	100/100	3	4-400 MCM	"	
LP6B	6th Floor Stair No. 1		1 15	1 5	2 20	2P SP	20A 20A	"	100/70	3	4-300 MCM	"	
LPPH-1A	Penthouse		3	3	6	SP	20A	Lugs Only	NEMA STD	1	3 No. 12	"	
LPBA	Basement Near Stair No. 1		9	3	12	SP	20A	Lugs Only	NEMA STD	3	4 No. 2	"	
LPBB	Basement Near Stair No. 1		11	3	14	SP	20A	Lugs Only	NEMA STD	3	4 No. 2	"	
LPBC	Basement Near Col. 32		5 0	5 1	10 1	SP 2P	20A 20A	Lugs Only	NEMA STD	3	4 No. 6	"	
LPBD	Basement Near Col. 8		6 0	4 1	10 1	SP 2P	20A 20A	Lugs Only	NEMA STD	3	4 No. 8	"	

should be noted that the code defines a lighting and appliance branch circuit panelboard as one having more than 10% of its overcurrent devices rated 30 amps or less, for which neutral connections are provided.

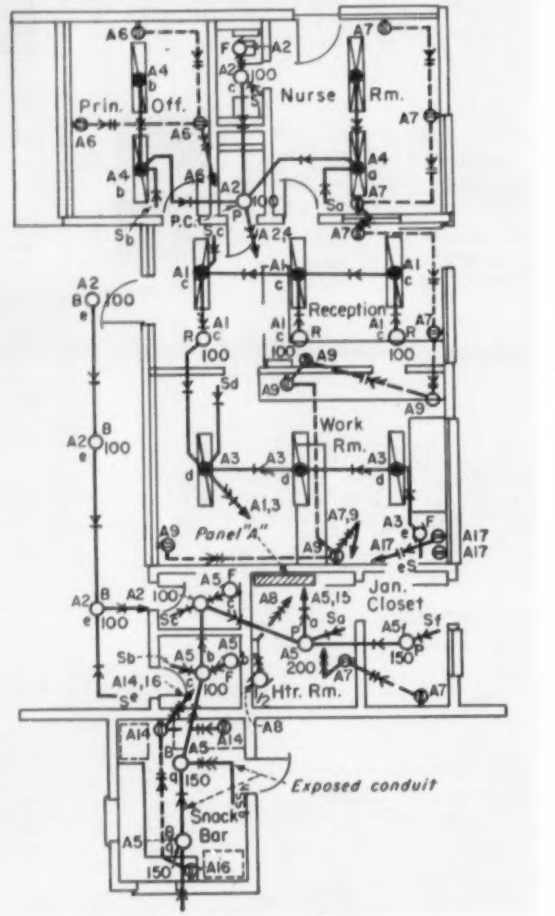
Overcurrent protection for panelboards should be carefully considered. A lighting and appliance branch circuit panelboard which is fed by a feeder protected at more than 200 amps, must be protected on its supply side by overcurrent devices rated not greater than the amp rating of the panelboard.

In the illustration shown below, the panelboard serves both lighting loads and receptacle and miscellaneous motor and signal loads on separate circuits.

SCHEDULE - LIGHTING PANEL "A"				
Ckt No.	No outlets	Watts bus 1	Watts bus 2	Remarks
1	6	900		15 A Ltg. Reception Rm.
2	6	700		↓ Closets and O. S.
3	4		800	↓ Work Rm
4	4		800	↓ Principal's and Nurse
5	8	1050		↓ Heads Htr Rm and Fans
6	3	1000		20A Rec. Nurse's Room
7	7		1050	↓ ↓ Reception Room
8	½ Hp		400	15A ← 15A-2P
9	6	900		20A Rec. Work Rm ½ Hp
10	½ Hp	400		15A ← Motor
11	1		500	↓ P. A. System
12	1		500	20A Intercom. System
13	1	500		↓ Clock, Bell & F. A. System
14	2	900		20A Recep's – Snack Bar
15	5		500	15A Snack Bar & Outside
16	1		500	20A Recep Snack Bar
17	2	500		20A Receps Work Rm.
18	–	1000		15A Spare
19	–		1000	↓ ↓
20	–		1000	↓ ↓
	Totals	7850	7050	
Main lugs only				



Plan - Covered Eating Area



Floor Plan - Light and Power

LEGEND

Fluorescent fixtures - capital letter and number indicate panel and circuit number per schedule. Lower case letter corresponds to letter on switch controlling unit

Duplex convenience receptacle - letter and number show panel and circuit

Incandescent lighting fixture - letter in circle gives fixture type from fixture schedule, "A2" gives panel and circuit, "e" indicates switch controlling unit and "100" is unit wattage

Se — *Switch - lower case letter indicates lighting units controlled by switch*

Fan motor

Concealed branch circuit home run

Concealed branch circuit conduit

Underfloor branch circuit home run

Underfloor branch circuit conduit

CIRCUITING DESIGNATIONS

One circuit, two wires, ½" conduit

Two circuits, three wires, ½" conduit

Two circuits, four wires, ¾" conduit

Two wires — *½" conduit*

Three wires

Four wires — *¾" conduit*

GRAPHICAL INTERPRETATION of electrical design involves the indication of types of electrical equipment on scaled representations of the building areas served by the equipment. The indications include the wire and raceway interconnections among the various elements and must convey all of the design concepts to the mind of the installer who will work from the plans. The above illustration shows the branch circuiting for a small school building with an outside covered eating area. A legend clarifies the use of symbols and a schedule of the panelboard serving the circuits shows the various loads. For the lighting circuits these loads are known from the lighting design which established the number and ratings of the various lighting units. For the ½-hp motor on circuits 8 and 10, the load is known. For receptacle circuits, loads are determined either by allowing 1½ amps for each outlet or by using load figures for known or estimated ratings of appliances. Rating of overcurrent protection for the branch circuits is given under "REMARKS" in the schedule.

CLASSIFICATIONS OF HAZARDOUS LOCATIONS
(Article 500, NEC)

There are three categories of hazardous locations:

Class I — Locations in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitible mixtures.

Class II — Locations which are hazardous because of the presence of combustible dust.

Class III — Locations which are hazardous because of the presence of easily ignitible fibers or flyings, but in which such fibers or flyings are not likely to be in suspension in air in quantities sufficient to produce ignitible mixtures.

Each Class of hazardous location is further subdivided into two divisions:

Division 1 — Locations where the hazardous condition is continuously present.

Division 2 — Locations in which the hazardous condition is not always present but in which the possibility of explosion or flash fire exists.

Various atmospheric mixtures have been grouped on the basis of their hazardous characteristics and serve to further classify hazardous locations:

Group A — Atmosphere containing acetylene.

Group B — Atmospheres containing hydrogen, or gases or vapors of equivalent hazard such as manufactured gases.

Group C — Atmospheres containing ethyl-ether vapors, ethylene or cyclo-propane.

Group D — Atmospheres containing gasoline, hexane, naphtha, benzine, butane, propane, alcohol, acetone, benzol, lacquer solvent vapors or natural gas.

Group E — Atmospheres containing metal dust including aluminum, magnesium and their commercial alloys.

Group F — Atmospheres containing carbon black, coal or coke dust.

Group G — Atmospheres containing flour, starch or grain dust

NOTES ON WIRING IN HAZARDOUS LOCATIONS

Class I Locations

Division 1 — Wiring must be in rigid metal conduit with threaded explosion proof joints and explosion proof boxes and fittings. All outlet and junction boxes, switches, controllers and motors must be of explosion-proof design. To prevent passage of gases, vapors or flames from one portion of the electrical system to another, conduit runs must have sealing fittings not more than 18 inches from the point where the conduit enters enclosures housing equipment which may produce sparks, arcs or high temperatures. Such seals must also be installed in each conduit run of 2-inch or larger size entering the enclosure or fitting housing terminals, splices or taps, and must be within 18 inches from the enclosure. Seals must also be used in conduit runs where they leave a hazardous area to enter a non-hazardous area. All conduit and box connections must be of the threaded type.

Division 2. — Requirements for explosion-proof equipment are essentially the same as for Division 1. However, conduit may be either rigid metal or electrical metallic tubing. Seals are required as set forth in section 5015, b.-1 and b.-2.

Class II Locations

Division 1 — Wiring must be in rigid conduit with threaded dust-tight fittings and boxes. Other equipment must also be of dust-tight design.

Division 2 — Wiring requirements are generally the same as for Division 1, but again either rigid or thinwall conduit may be used.

Class III Locations

Divisions 1 and 2 require rigid conduit with threaded fittings and boxes designed to prevent escape of sparks or flames. Fixtures, switches and controller enclosures as well as motors must be of dust-tight construction.

Motor Branch Circuits

Design of circuits for motor loads and their controls involves particular consideration of factors and conditions which do not present serious problems in the design of ordinary lighting and appliance branch circuits. Motor loads are usually large loads and require careful wiring and protection of conductors and equipment to assure safe and reliable operation. In any plant or building, of course, the problem of providing maximum safety and reliability must be solved along with other problems—minimizing voltage drop, avoiding excessive copper loss, providing sufficient flexibility for changing locations of equipment, designing for ease and economy of maintenance of the motors and equipment and providing spare capacity in the equipment for increased loads in the future.

Basically, Article 430 of the code provides the requirements for safe and reliable operation of motor circuits. This article contains the general requirements; other articles contain specific references to motor applications — in cranes, hoists, elevators, machine tools, hazardous locations and in such occupancies as garages, service stations, bulk storage plants and other industrial areas.

Except for sealed (hermetic-type) refrigeration compressor motors, values for motor current ratings given in Tables 21 to 24, Chapter 10 of the code, must be used in sizing conductors, switches, branch circuit overcurrent devices, etc., instead of the motor nameplate value of current. However, the motor nameplate current should be used in determining the motor running overcurrent protection. For sealed refrigeration compressor motors, the nameplate current is used in determining size of conductors, circuit overcurrent protection and motor running overcurrent protection.

Size of Conductors

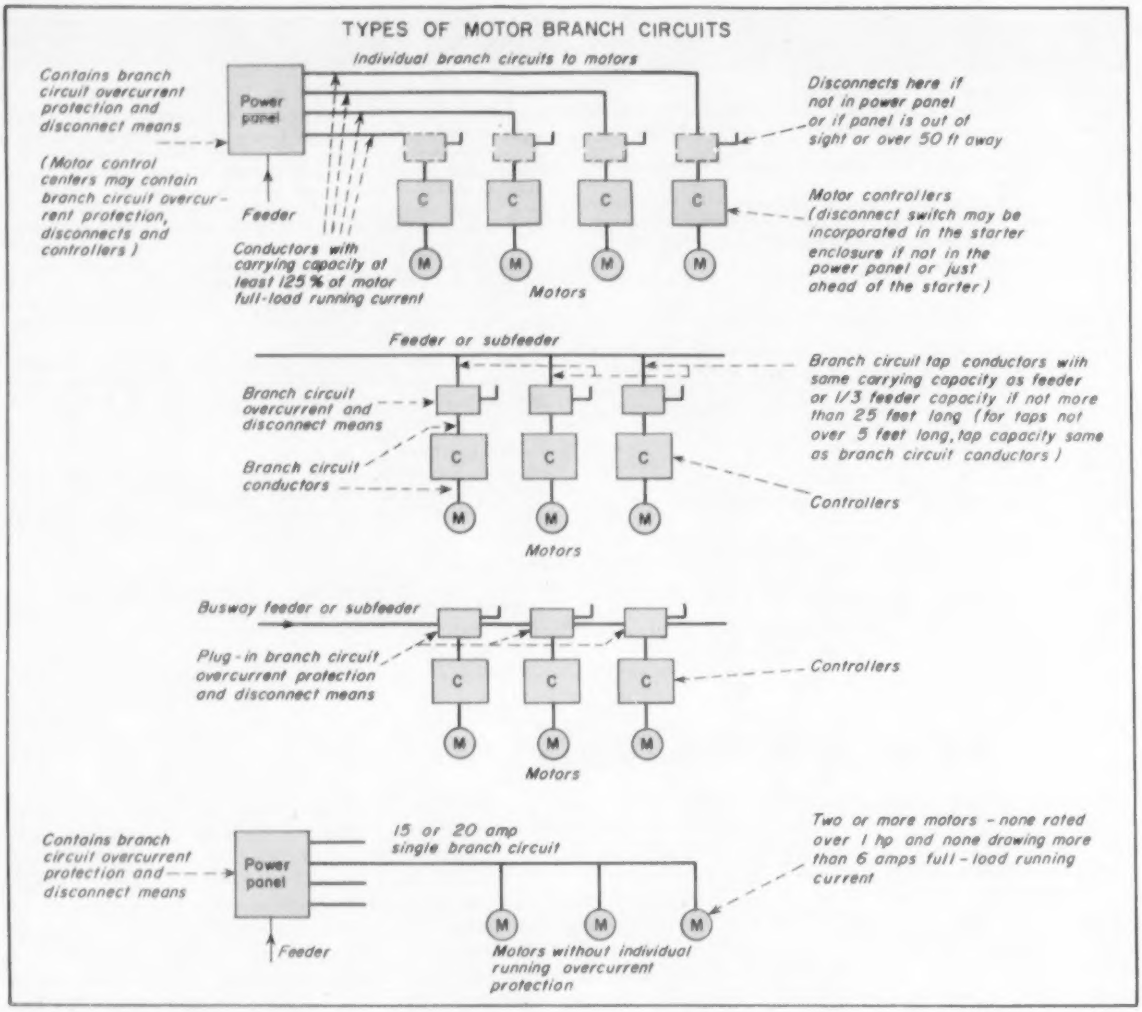
Branch circuit conductors serving only one motor must have a current-carrying capacity not less than 125% of the full-load current rating of the motor. Section 4312 of the code also includes requirements for sizing individual branch circuit conductors serving motors used for short-time, intermittent, periodic or varying duty.

Conductors connecting the secondary of a wound-rotor induction motor to the controller must have a carrying capacity at least equal to 125% of the motor's full load secondary current if the motor is used for continuous duty. If the motor is used for less than continuous duty, the conductors must have capacity not less than the percentage of full-load secondary current given in the table of section 4312. Conductors from the secondary of a wound rotor induction motor to its starting resistor must have a capacity rating in accordance with the duty classification of the resistor as given in section 4313.

Protection for Motors

Overcurrent protection in motor branch circuits is intended to protect the motors, motor control equipment and the branch circuit conductors against excessive heating due to overloads and against grounds and shorts. Design considerations for such protection vary with the size of motors, the operating duty cycle and the type of motor. Typical requirements for running overcurrent protection are as follows:

For motors of more than one horsepower, if used for continuous duty, running overcurrent protection must be provided. This may be an external overcurrent device actuated by the motor running current and set to open at not more than 125% of the motor full-load current for motors with a temperature rise not over 40C or 115% of



MOTOR BRANCH CIRCUITS may be supplied as shown in these diagrams, within the limitations outlined by the code. Where motors are closely grouped in one area, the use of a motor control center with circuit protection, disconnects and controllers offers operating and maintenance advantages. The use of busway systems offers many advantages in industrial applications.

the motor full-load current for all other motors. Or protection might be provided by a device integral with the motor and responsive to motor current or motor current and temperature. For motors over 1500 hp, an embedded temperature detector may be used to cause opening of the supply when the temperature gets too high.

Motors of one horsepower or less, manually started, are protected against overcurrent by the branch circuit protection if the motor is within sight from the starter. A distance of more than 50 ft is considered out of sight.

Automatically-started motors of one horsepower or less must be protected against running overcurrent in the same way as motors rated over one horsepower. That is, a separate overcurrent device or an integral device. In the case of such a motor, however, it may be considered protected against running overcurrent if it is part of an approved assembly "which does not subject the motor to overloads and which is also equipped with other safety controls (such as the safety combustion controls of a domestic oil burner) which protect the motor against damage due to stalled rotor current." Or if the impedance of the winding of a motor is sufficient to prevent overheating with stalled rotor, the branch circuit protection is considered running protection.

The branch circuit protection is considered sufficient protection against running overcurrent for motors which have inherently short duty cycles—intermittent, periodic or varying duty.

A motor is considered to be used for continuous duty unless the nature of the load it drives is such that it cannot operate continuously under any condition of use.

Branch Circuit Protection

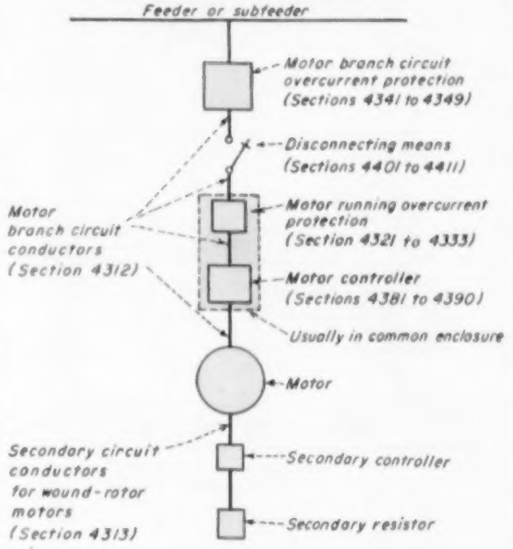
Code provisions for the protection of branch circuit conductors feeding motors are covered in sections 4341 to 4349. The overcurrent device protecting an individual motor branch circuit must be able to carry the motor starting current. It must have time delay to allow the motor to start and come up to speed. Tables 26 and 27 in Chapter 10 of the code give the required overcurrent rating values for various motor loads. Table 20 in Chapter 10 gives ratings of fuses for circuit overcurrent protection.

Code Table 21 (Proposed for 1956 National Electrical Code)

MOTOR BRANCH CIRCUITS

1. For continuous-duty motors, the load on the branch circuit feeding a single motor is taken as 125% of the full-load rated current of the motor.
2. The load on a branch circuit supplying a motor in a class of service having short-time duty depends upon the type of loading. In most cases, the load is not greater than the percentages of full-load rated current given in table of Sec. 4312 of the NEC.
3. The load on conductors connecting the secondary of a wound rotor induction motor to its controller is taken as 125% of the rated full-load secondary current for continuous-duty motors, and not less than the percentages of full load current for short-time duty motors given in table of Sec. 4312 of the NEC. Sec. 4313, NEC, covers load on conductors connecting the controller with secondary resistors.
4. The load on conductors supplying two or more motors is taken as not less than 125% of the full-load current rating of the highest rated motor in the group plus the sum of the full-load current ratings of the remainder of the motors in the group.
5. The load on conductors supplying motors and, in addition, lighting or appliances, is taken as the sum of the separate motor load and lighting or appliance load.

MOTOR BRANCH CIRCUIT
SEQUENCE OF PROTECTION
AND NEC REFERENCE SECTIONS



A single branch circuit may be used to supply two or more motors as follows:

1. Two or more motors, each rated not more than 1 horsepower and each drawing not over 6 amps full-load current, may be used on a branch circuit protected at 20 amps at 125 volts or less or 15 amps at 600 volts or less. Individual running overcurrent protection is generally unnecessary in such a circuit. Conductors supplying two or more motors must have a current carrying capacity equal to 125% of the full-load current of the largest of the motors plus the sum of the full-load currents of the other motors supplied.

2. Two or more motors of any rating may be connected to one branch circuit if each motor has running overcurrent protection, the overcurrent devices and controllers are approved for group installation, the branch circuit fuse rating is in accordance with Tables 26 and 27 for the largest motor plus the sum of the full-load current ratings of the other motors. The branch circuit fuses must not be larger than 4 times the rating of the thermal cutout or relay protecting the smallest motor of the group.

Devices other than fuses used for motor running overcurrent protection and circuit breakers used to protect motor branch circuits must have a continuous current rating not less than 115% of the full-load current rating of the motor.

Sections 4371 to 4374 of the code give requirements for remote-control circuits used with motor loads.

Motor Disconnects

Depending upon the size and application of a motor, some provision must be made for disconnecting the motor from the line for maintenance and repair. General requirements for motor disconnects call for a motor-circuit switch rated in horsepower or a circuit breaker. Exceptions to this requirement are as follows:

1. The branch circuit overcurrent device may serve as the disconnecting means for stationary motors rated one-eighth horsepower or less.

2. A general-use switch rated at twice the motor full-load current rating may be used as the disconnecting means for stationary motors rated at 2 hp or less and 300 volts or less.

3. From 2 to 50 hp, motors used with compensator types of controllers may have a general-use switch for the disconnecting means under conditions given in section 4402 of the code.

4. Motors over 50 hp may have a motor-circuit switch also rated in amps, a general-use switch or an isolating switch for their disconnect.

5. The plug and receptacle used for connecting portable motors to their circuit may serve as the disconnecting means.

In a motor branch circuit, every switch in the circuit in sight from the controller must satisfy the foregoing requirements. And the disconnect switch must be able to carry at least 115% of the nameplate current rating of the motor. It must disconnect both the motor and the controller from all ungrounded supply conductors. For sealed refrigeration compressors, section 4403 gives the procedure for using code tables to determine disconnect capacity.

In general, each motor is provided with a separate disconnecting means. However, for motors under 600 volts, a single disconnect may sometimes serve a group of motors. Such a disconnect must have a rating sufficient to handle a single load equal to the sum of the horsepower ratings or current ratings. The single disconnect may be used for a group of motors

Code Table 21 (Proposed for 1956 National Electrical Code)			
Full-Load Current* Direct-Current Motors			
HP	115 V	230 V	550 V
¼	3	1.5	—
⅓	3.8	1.9	—
½	5.4	2.7	—
¾	7.4	3.7	1.6
1	9.6	4.8	2.0
1½	13.2	6.6	2.7
2	17	8.5	3.6
3	25	12.5	5.2
5	40	20	8.3
7½	58	29	12
10	76	38	16
15	112	56	23
20	148	74	31
25	184	92	38
30	220	110	46
40	292	146	61
50	360	180	75
60	430	215	90
75	536	268	111
100	—	355	148
125	—	443	184
150	—	534	220
200	—	712	295

Code Table 22 (Proposed for 1956 National Electrical Code)			
Full-Load Current* Single-Phase AC Motors			
HP	115 V	230 V	440 V
1/6	4.4	2.2	—
¼	5.8	2.9	—
⅓	7.2	3.6	—
½	9.8	4.9	—
¾	13.8	6.9	—
1	16	8	—
1½	20	10	—
2	24	12	—
3	34	17	—
5	56	28	—
7½	80	40	21
10	100	50	26

*These values are for motors with usual speeds and torque characteristics. Nameplate current values should be used for motors with low speeds or high torques.

To obtain full-load currents of 208- and 200-volt motors, increase 230-volt current values by 10 and 15 percent, respectively.

Code Table 24 Full-Load Current* Three-Phase AC Motors

	Induction Type Squirrel-Cage and Wound Rotor Amperes					Synchronous Type Unity Power Factor Amperes			
HP	110V	220V	440V	550V	2300V	220V	440V	550V	2300V
½	4	2	1	.8	...	...	...	...	. .
¾	5.6	2.8	1.4	1.1	...	...	...	...	...
1	7	3.5	1.8	1.4	...	...	...	...	...
1½	10	5	2.5	2.0	...	...	...	...	...
2	13	6.5	3.3	2.6	...	...	...	. .	...
3	...	9	4.5	4	...	...	...	...	...
5	...	15	7.5	6	...	...	...	...	...
7½	...	22	11	9	...	...	...	...	...
10	...	27	14	11	...	...	...	...	...
15	...	40	20	16	...	...	...	...	. .
20	...	52	26	21	...	...	...	...	...
25	...	64	32	26	7	54	27	22	5.4
30	...	78	39	31	8.5	65	33	26	6.5
40	...	104	52	41	10.5	86	43	35	8
50	...	125	63	50	13	108	54	44	10
60	...	150	75	60	16	128	64	51	12
75	...	185	93	74	19	161	81	65	15
100	...	246	123	98	25	211	106	85	20
125	...	310	155	124	31	264	132	106	25
150	...	360	180	144	37	...	158	127	30
200	...	480	240	192	49	...	210	168	40

For full-load currents of 208- and 200-volt motors, increase the corresponding 220-volt motor full-load current by 6 and 10 per cent, respectively.

*These values of full-load current are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for especially low speeds or high torques may require more running current, in which case the nameplate current rating should be used.

driving different parts of a single piece of apparatus, for several motors on one branch circuit or for a group of motors in a single room within sight from the disconnect location.

An important requirement in motor circuits is that the disconnect be within sight from the controller location or be constructed and designed for locking in the open position. A distance of over 50 ft is considered out of sight.

Motor Controls

According to the code, the term "controller" includes any switch or device normally used to start and stop the motor. In general, a motor controller must have a horsepower rating not lower than the rating of the motor. Motors under one-eighth horsepower which are normally left running and are not subject to damage from overload or failure to start, such as clock motors, may use the branch circuit protective device for the controller. Portable motors up to one-third horsepower may use their plug and receptacle connection as a controller. For stationary motors up to two horsepower, and up to 300 volts, a general-use switch rated twice the full-load motor current may be used as the controller. A branch circuit breaker, rated only in amps, may be used as a motor controller.

Although motors are generally provided with individual means for control, a single controller may serve a group of motors, rated not over 600 volts, under the same conditions as a single disconnect may be used.

Sections 4421 to 4425 cover requirements for motors rated over 600 volts. Article 710 of the code deals specifically with "Circuits and Equipment Operating at More Than 600 Volts Between Conductors."

Design for motors over 600 volts includes protection of live parts and grounding.

FULL-LOAD CURRENTS for general motor applications, excepting sealed (hermetic-type) refrigeration compressor motors, shall be taken from these tables for determining the current-carrying capacity of conductors, switches, branch circuit overcurrent devices, etc., instead of using motor nameplate ratings. Motor running overcurrent protection, however, must be based on the motor nameplate current rating.

Voltage Regulation

To assure proper and efficient operation of motors, the matter of voltage regulation must be considered carefully. Many factors—number of motors, sizes and types of motors, duty cycles, load densities, type of distribution system, loading of various feeders, power factor — are related to the design problem of assuring necessary level and stability of voltages for motors. The matter of voltage regulation follows through every step in design and must be accounted for in sizing conductors and selecting equipment for the system.

Voltage drop from the source of voltage supply to any motor in the system must not exceed 5%. Normally, proper power feeder design will limit voltage drop to 3%, leaving a maximum permissible voltage drop of 2% in any motor branch circuit under full-load conditions. However, a 1% maximum circuit drop is recommended. To meet this requirement, assuring all the advantages of motor operation at proper value, voltage drop calculations should be based on all of the previously mentioned factors which affect voltage drop. Copper loss due to conductor resistance and current flow represents a power loss in heat and should be minimized by up-sizing the conductors where the motor will be running at or near full load for long periods. Power factor should be taken into consideration in all calculations, using the known value of PF or an 80% assumed value.

Depending upon the results of study of the voltage drop and power factor relationship, use of corrective measures for improving power factor may be designed into motor branch circuits. At individual motor locations, power factor correcting capacitors offer reduction in required carrying capacity and improved voltage regulation. Voltage stability as it might be af-

CIRCUIT PROTECTION for motor branch circuits must be provided in accordance with the ratings or settings of overcurrent protective devices given in these tables. The motor branch circuit overcurrent device is required to protect the conductors, the controls and the motor itself against shorts and grounds. The overcurrent device must be capable of carrying the starting current. Table 20 gives fuse ratings to correspond to Tables 26 and 27.

CODE TABLE 26

MAXIMUM RATING OR SETTING OF MOTOR-BRANCH-CIRCUIT PROTECTIVE DEVICES FOR MOTORS WITH A CODE LETTER INDICATING LOCKED-ROTOR KVA

Type of Motor	Percent of Full-Load Current		
	Fuse Rating (See Table 20, Columns 7, 8, 9 and 10)	Circuit-Breaker Setting	
		Instantaneous Type	Time Limit Type
All ac single-phase and polyphase squirrel-cage and synchronous motors with full-voltage, resistor or reactor starting:			
Code Letter A	150	—	150
Code Letter B to E	250	—	200
Code Letter F to V	300	—	250
All ac squirrel-cage and synchronous motors with autotransformer starting:			
Code Letter A	150	—	150
Code Letter B to E	200	—	200
Code Letter F to V	250	—	200

CODE TABLE 27

MAXIMUM RATING OR SETTING OF MOTOR-BRANCH-CIRCUIT PROTECTIVE DEVICES FOR MOTORS NOT MARKED WITH A CODE LETTER INDICATING LOCKED-ROTOR KVA

Type of Motor	Percent of Full-Load Current		
	Fuse Rating (See Table 20, Columns 7, 8, 9 and 10)	Circuit-Breaker Setting	
		Instantaneous Type	Time Limit Type
Single-phase, all types	300	—	250
Squirrel-cage and synchronous (full-voltage, resistor or reactor starting)	300	—	250
Squirrel-cage and synchronous (autotransformer starting):			
Not more than 30 amps	250	—	200
More than 30 amps	200	—	200
High-reactance squirrel-cage:			
Not more than 30 amps	250	—	250
More than 30 amps	200	—	200
Wound-rotor	150	—	150
Direct-current:			
Not more than 50 hp	150	250	150
More than 50 hp	150	175	150

NOTES:

When overcurrent protection specified in these tables is not sufficient for the starting current of a motor, the overcurrent protection may be increased but shall in no case exceed 400 percent of the motor full-load current.

The values given in the last column of each table also cover ratings of non-adjustable, time-limit types of circuit-breakers which may be used in accordance with the above allowance for increase in overcurrent protection.

If values of branch circuit protection given in the tables do not correspond to standard ratings of protective devices, the next higher rating or setting may be used.

Synchronous motors of the low-torque, low-speed type (usually 450 rpm or lower) such as are used to drive reciprocating compressors, pumps, etc., which start up unloaded, do not require a fuse rating or circuit-breaker setting in excess of 200 percent of full-load current.

Code Table 20—Conductor Sizes And Overcurrent Protection For Motors

The values shown for running protection in Columns 5 and 6 must be modified if nameplate full load current values are different. Conductor sizes shown in Columns 2 and 3 may be smaller for certain motors. The current values shown in Columns 5 and 6 must be reduced by 8 per cent for all motors other than open type motors marked to have a temperature rise not over 40 degrees C.

Full load current rating of motor amperes	Minimum size conductor in raceways. For conductors in air or for other insulations see tables 1 and 2. AWG and MCM. Type R, Type T	Type RH	For Running Protection of Motors: Maximum rating of non-adjustable protective devices, Amperes	For Running Protection of Motors: Maximum setting of adjustable protective device, Amperes	Maximum Allowable Rating or Setting of Branch Circuit Protective Devices: **With Code Letters** Single-phase and squirrel cage and synchronous. Full voltage, resistor and reactor starting, Code letters F to V inc. **Without Code Letters** Same as above.	**With Code Letters** Single-phase and squirrel cage and synchronous. Full voltage, resistor or reactor starting, Code letters B to E inc. Auto-transformer starting, Code letters F to V inclusive. **Without Code Letters** Squirrel cage and synchronous auto-transformer starting. High reactance squirrel cage. Both not more than 30 amperes	**With Code Letters** Squirrel cage and synchronous Auto-transformer starting, Code letters B to E inclusive. **Without Code Letters** Both more than 30 amperes	**With Code Letters** All motors. Code letter A. **Without Code Letters** DC and wound-rotor motors
Col. No. 1	2	3	5	6	7	8	9	10
1	14	14	2	1.25	15	15	15	15
2	14	14	3	2.50	15	15	15	15
3	14	14	4	3.75	15	15	15	15
4	14	14	6	5.0	15	15	15	15
5	14	14	8	6.25	15	15	15	15
6	14	14	8	7.50	20	15	15	15
7	14	14	10	8.75	25	20	15	15
8	14	14	10	10.0	25	20	20	15
9	14	14	12	11.25	30	25	20	15
10	14	14	15	12.50	30	25	20	15
11	14	14	15	13.75	35	30	25	20
12	14	14	15	15.00	40	30	25	20
13	12	12	20	16.25	40	35	30	20
14	12	12	20	17.50	45	35	30	25
15	12	12	20	18.75	45	40	30	25
16	12	12	20	20.00	50	40	35	25
17	10	10	25	21.25	60	45	35	30
18	10	10	25	22.50	60	45	40	30
19	10	10	25	23.75	60	50	40	30
20	10	10	25	25.0	60	50	40	30
22	10	10	30	27.50	70	60	45	35
24	10	10	30	30.00	80	60	50	40
26	8	10	35	32.50	80	70	60	40
28	8	10	35	35.00	90	70	60	45
30	8	8	40	37.50	90	70	60	45
32	8	8	40	40.00	100	80	70	50
34	6	8	45	42.50	110	90	70	60
36	6	8	45	45.00	110	90	80	60
38	6	6	50	47.50	125	100	80	60
40	6	6	50	50.00	125	100	80	60
42	6	6	50	52.50	125	110	90	70
44	6	6	60	55.0	125	110	90	70
46	4	6	60	57.50	150	125	100	70
48	4	6	60	60.0	150	125	100	80
50	4	6	60	62.50	150	125	100	80
52	4	6	70	65.0	175	150	110	80
54	4	4	70	67.50	175	150	110	90
56	4	4	70	70.00	175	150	120	90
58	3	4	70	72.50	175	150	120	90
60	3	4	80	75.00	200	150	120	90
62	3	4	80	77.50	200	175	125	100
64	3	4	80	80.00	200	175	150	100
66	2	4	80	82.50	200	175	150	100
68	2	4	90	85.00	225	175	150	110
70	2	3	90	87.50	225	175	150	110
72	2	3	90	90.00	225	200	150	110
74	2	3	90	92.50	225	200	150	125
76	2	3	100	95.00	250	200	175	125
78	1	3	100	97.50	250	200	175	125
80	1	3	100	100.00	250	200	175	125
82	1	2	110	102.50	250	225	175	125
84	1	2	110	105.00	250	225	175	150
86	1	2	110	107.50	300	225	175	150
88	1	2	110	110.00	300	225	200	150
90	0	2	110	112.50	300	225	200	150
92	0	2	125	115.00	300	250	200	150
94	0	1	125	117.50	300	250	200	150
96	0	1	125	120.00	300	250	200	150
98	0	1	125	122.50	300	250	200	150
100	0	1	125	125.00	300	250	200	150
105	00	1	150	131.5	350	300	225	175
110	00	0	150	137.5	350	300	225	175
115	00	0	150	144.0	350	300	250	175
120	000	0	150	150.0	400	300	250	200
125	000	00	175	156.5	400	350	250	200
130	000	00	175	162.5	400	350	300	200
135	0000	00	175	169.0	450	350	300	225
140	0000	00	175	175.0	450	350	300	225
145	0000	000	200	181.5	450	400	300	225
150	0000	000	200	187.5	450	400	300	225
155	0000	000	200	194.0	500	400	350	250
160	250	000	200	200.0	500	400	350	250
165	250	0000	225	206.	500	450	350	250
170	250	0000	225	213.	500	450	350	300
175	300	0000	225	219.	600	450	350	300
180	300	0000	225	225.	600	450	400	300
185	300	0000	250	231.	600	500	400	300
190	300	250	250	238.	600	500	400	300
195	350	250	250	244.	600	500	400	300
200	350	250	250	250.	600	500	400	300
210	400	300	250	263.	....	600	450	350
220	400	300	300	275.	....	600	450	350
230	500	300	300	288.	....	600	500	350
240	500	350	300	300.	....	600	500	400

POWER PANEL SCHEDULE																
Panel Designation	Location	Branch Cct. Equip.	Mains		Branch Circuits				Service		Conductor			Motor	
			Type	Cap	No.	Poles	Frame	Trip Calibr.	Phase	Voltg.	No.	Size	Type	Equipment	H P
PHP	Pent House	Cct. Bkr.	Lugs Only	NEMA Std.	–	–	–	–	3	120/208			R		
					1	3	225	125	3	"	3	2	R	*Inter. Zone Fan*	25
					2	3	100	50	3	"	3	8	R	*Exter. Zone Fan*	10
					3	3	50	15	3	"	3	12	R	*Booster Pump*	2
					4	3	50	15	3	"	3	12	R	*Toilet Exh. Fan*	3/4
					5	3	50	15	3	"	3	12	R	*Dehumid. Spray Pump*	1/2
					6	3	50	15	3	"	3	12	R	*Power Roof Ventilator*	1
					7	3	50	15	3	"	3	12	R	" " "	1
					8	2	50	20	1	"	3		R	*Ltg. Panel LPPHIA*	
					9	3	50	15	3	120/208	3	12	R	*Roof Vent*	1 3/8
					10,11,12	3	50	*Spares*			–				
PP3	3rd. Fl. Mech. Rm.	Cct. Bkr.	Lugs Only	NEMA Std.	–	–	–	–	3	120/208			R		
					1	3	50	15	3	"	3	12	R	*Dehum. Spray Pump*	1/2
					2	3	225	100	3	"	3	4	R	*A C Unit "C"*	20
					3	1	50	15	1	"	2	12	R	*Filter Motor*	1/6
					4	1	50	15	1	"	2	12	R	*Bd. Rm. Exh. Fan*	1/4
					5	3	50	15	3	120/208	3	12	R	*A C Unit "J"*	1/2
					6	1	50	*Spare*							
					7	3	50	*Spare*							
					8	3	50	*Spare*							
BPP	Bsm't Power	Cct. Bkr.	Lugs Only	NEMA Std.	–	–	–	–	3	120/208			R		
					1	3	50	15	3	"	3	12	R	*Evap. Cond. Fan*	1
					2	3	50	15	3	"	3	12	R	*Ch. D.W. Pump*	1 1/2
					3	3	50	15	3	"	3	12	R	*Ch. D.W. Pump*	2
					4	3	50	30	3	"	3	12	R	*D.W. Compr.*	3
					5	3	50	30	3	"	3	12	R	*D.W. Compr.*	3
					6	1	50	20	1	"	2	12	R	*Evap. Cond. Spray Pump*	1/3
					7	1	50	20	1	"	2	12	R	*D.W. Pump*	1/4
					8	1	50	20	1	"	2	12	R	" "	1/4
					9	1	50	20	1	120/208	2	12	R	*Boiler Cont.*	1/4
					10,11,12	3	50	*Spares*							

POWER PANELS supplying motor branch circuits should be described both as to their feeds and the circuits they serve, as shown in this "Power Panel Schedule". Data on branch circuit protection includes frame size and trip calibration for CB's.

fected by starting currents of motors frequently coming on is generally a consideration in feeder design but should not be overlooked in circuits serving more than one motor.

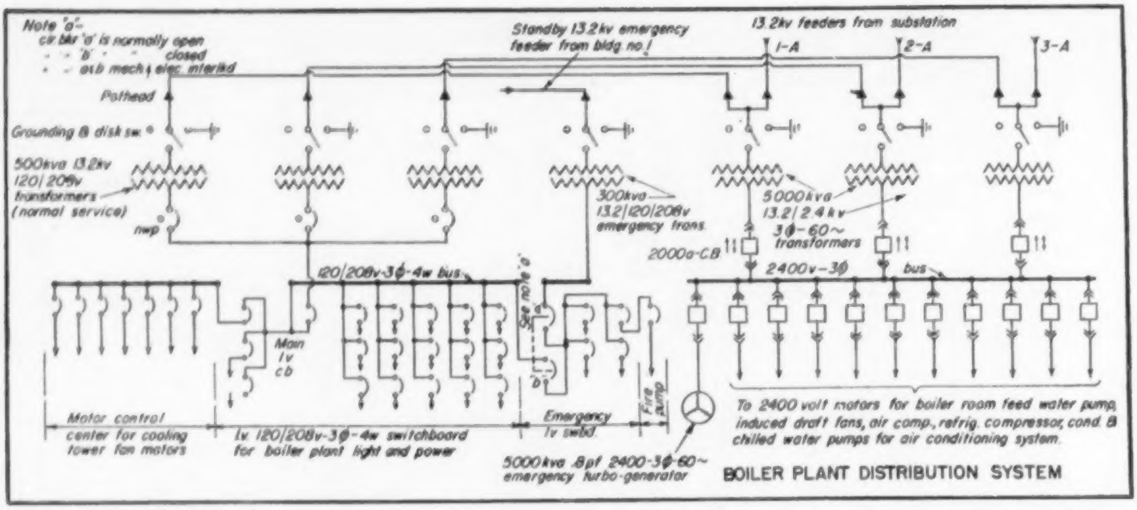
Layout of Circuits

Based on the foregoing rules and considerations, motor branch circuits can be designed for any types of occupancy. Generally, motor circuit requirements for commercial and institutional buildings are concerned with known loads which are fairly permanent in their size and location. These loads include refrigeration and air conditioning compressors, pumps, elevators, escalators, blowers and fans. Such loads can be served by many types of wiring systems without special provisions for flexibility of power circuiting. Industrial plants, on the other hand, require considerable power circuiting flexibility to accommodate moving of motors, shifting of production lines and expansion of motor loads. To provide this necessary flexibility, motor circuits may be fed from plug-in busway, from wireways, from oversize conduit and raceways which will allow change and expansion in the wiring or, in the case where many small motors are to be supplied, an underfloor raceway system. Spare capacity for increased motor loads is a design consideration for motor feeders and subfeeders. Spare capacity should be included in the motor circuit panelboard where required. By using sectional type panelboards with interchangeable units and oversize raceway for branch circuit wiring, future increase in size of the motor on the circuit and increase in associated branch circuit equipment is greatly facilitated.

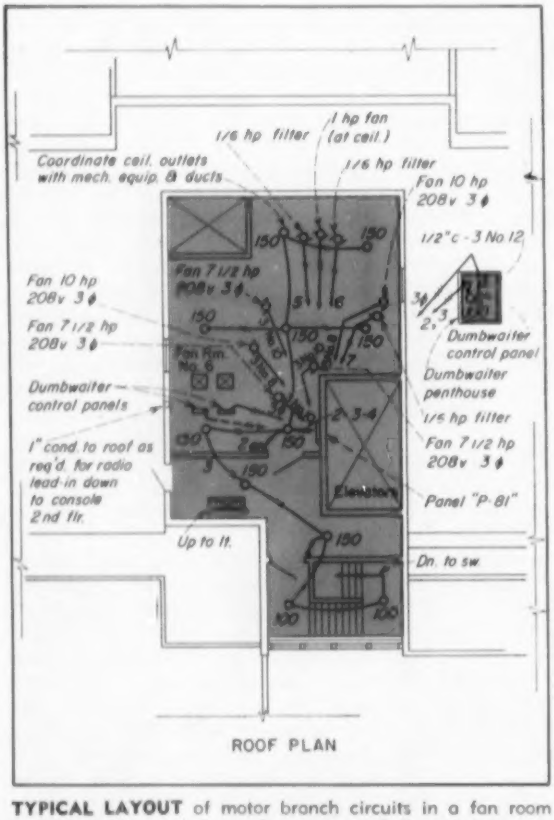
Laying out wiring to serve two or more motors may be made according to one of several plans. First, each motor may be served by a separate branch circuit from a power panel or distribution center. Second, individual branch circuits to motors may be tapped from a feeder or subfeeder at various points along its length of run, without using a branch circuit distribution center. Third, individual circuits to motors may be tapped from a feeder without individual overcurrent protection for the taps, provided they are carried direct to the disconnecting means or controller for each motor. Such taps must have the same carrying capacity as the feeder if they are over 25 ft long. If they are under 25 ft long, they must have a carrying capacity at least equal to one-third the carrying capacity of the feeder. In such cases, the motor branch circuit protection is often omitted and the branch circuit originates at the motor controller. Fourth, individual branch circuits to motors may originate at controllers or disconnects fed directly by a feeder or subfeeder. Fifth, two or more motors may be connected to a single branch circuit under the conditions previously given for several motors on one branch circuit.

The diagram of types of motor branch circuits, shown on page 90, covers the most common layouts of motor circuits, supplied either from panelboards or switchboards or from taps to a feeder or subfeeder as shown. Successful design of motor branch circuits depends upon thorough understanding of the ways in which the required types of protection may be combined.

← **CIRCUIT DATA** for motor branch circuits is given in this table. For any motor, the full-load current rating is obtained from Tables 21 to 24. Then, using this current value, the Table 20 provides required size of conductor to supply the motor, gives the rating or setting for the required running overcurrent protection and gives the ratings of fuses for maximum allowable branch circuit overcurrent protection.



MOTOR BRANCH CIRCUITS shown in this distribution diagram of the boiler plant of a large medical research building are derived from 3-phase, 4-wire 120/208-volt motor control center for fan motors, from a 120/208-volt switchboard for general purpose motor applications and from a 2400-volt, 3-phase circuit breaker switchboard supplying 2400-volt circuits to motors for pumps, compressors, air conditioning system, etc.



ROOF PLAN

TYPICAL LAYOUT of motor branch circuits in a fan room on top of a hospital shows the circuit symbols and design information which must guide the installer in carrying out the plan. Other data on the motors and controls are incorporated in the job specifications.

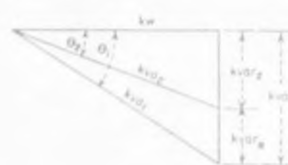
Application of Power Factor Capacitors

Power factor capacitors can be connected across electric lines to neutralize the effect of lagging power-factor loads, thereby reducing the current drawn for a given kilowatt load. In a distribution system, small capacitor units may be connected at the individual loads or the total capacitor kilovolt-amperes may be grouped at one point and connected to the main. Although the total kvar of capacitors is the same, the use of small capacitors at the individual loads reduces current all the way from the loads back to the source and thereby has greater PF corrective effect than the one big unit on the main, which reduces current only from its point of installation back to the source.

Calculating Size of Capacitor:

Assume it is desired to improve the power factor a given amount by the addition of capacitors to the circuit.

Then $kvar_R = kw \times (\tan \Theta_1 - \tan \Theta_2)$



where $kvar_R$ = rating of required capacitor
$kvar_1$ = reactive kilovolt-amperes at original PF
$kvar_2$ = reactive kilovolt-amperes at improved PF
Θ_1 = original phase angle
Θ_2 = phase angle at improved PF
kw = load at which original PF was determined.

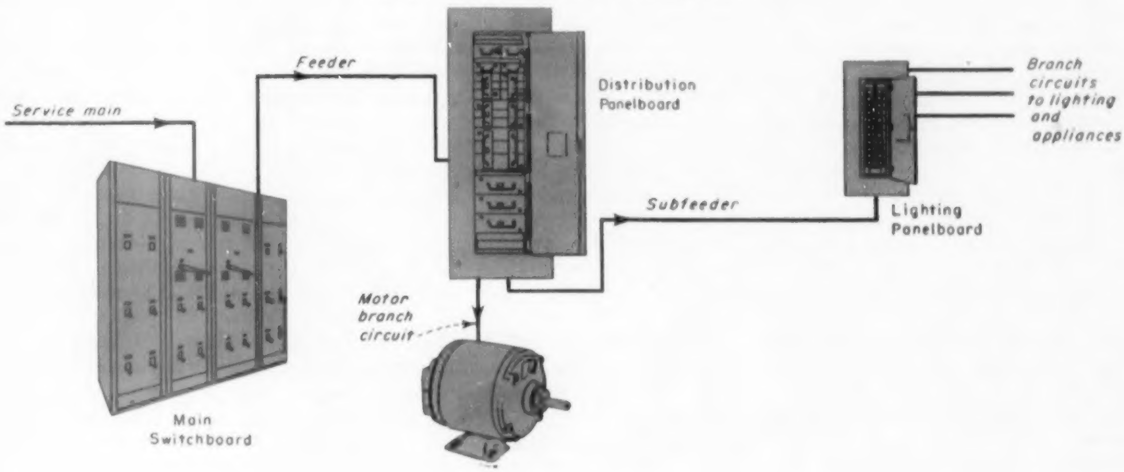
NOTE: The phase angles Θ_1 and Θ_2 can be determined from a table of trigonometric functions using the following relationships:

Θ_1 = The angle which has its cosine equal to the decimal value of the original power factor (e.g., 0.70 for 70% PF; 0.65 for 65% PF; etc.)

Θ_2 = The angle which has its cosine equal to the decimal value of the improved power factor.

Distribution

ELECTRICAL SYSTEM TERMINOLOGY



IN ANY electrical system, the distribution system involves the methods and equipment used to carry power from the service equipment to the overcurrent devices protecting the branch circuits. The distribution system carries power to lighting panelboards, power panelboards, motor control centers and to the branch circuit protective devices for individual motor or power loads. Depending upon the type of building, the size and nature of the total load, various economic factors and local conditions, a distribution system may operate at a single voltage level or may involve one or more transformations of voltage. A distribution system might also incorporate change in frequency of alternating-current power or rectification from alternating-current to direct-current power.

Design of a distribution system, therefore, is a matter of selecting circuit layouts and equipment to accomplish electrical actions and operations necessary for the conditions of voltage, current and frequency. This means relating such factors as service voltage, distribution voltage or voltages, conductors, transformers, converters, switches, protective devices, regulators and power factor corrective means to economy, load conditions, continuity of service, operating efficiency and future power requirements. Of course, the factors of capacity, accessibility, flexibility and safety must be carefully included in design considerations for distribution, as explained in the section on "General Considerations".

Distribution Systems

The basic classification of distribution systems is according to voltage level used to carry the power either directly to the branch circuits or to load-center transformers or substations at which feeders to branch circuits originate. The following are the most common types of distribution systems based on voltage:

1. 120/240-volt, 3-wire, single-phase combination light and power distribution to lighting and appliance branch circuit panelboards and to power panels. This type of system is restricted to applications where the total load is small and is primarily lighting. Stores, small schools and other small commercial occupancies use this system. In most cases of small commercial buildings, the use of 120/208-volt 3-phase distribution offers greater economy due to higher operating efficiency of 3-phase circuits. In those cases where 120/240-volt distribution is used as the basic distribution, the service to the premises is made at that voltage. Of course, 120/240-volt distribution is frequently an effective and economical system for lighting-subfeeder distribution in electrical systems which use a higher-voltage basic distribution system with load-center step-down to utilization voltages for local and incidental lighting and receptacle circuits.

2. 120/208-volt, 3-phase, 4-wire distribution is the most common type of system used in commercial buildings, in some institutional occupancies and in small industrial shops with limited electrical loads. This system offers substantial economy over the 120/240-volt system in the amount of copper conductor required to carry a given amount of power to a load. It is a combination light and power distribution system, providing 120 volts phase-to-neutral for lighting and single-phase loads and 208 volts phase-to-phase for single- or 3-phase motor or other power loads. This distribution system is used as the basic distribution in those occupancies in which the service to the building is of the same voltage. It is also the most common sub-distribution system for lighting and receptacle circuits in those occupancies using higher-voltage distribution to load centers.

3. 240-volt, 3-phase, 3-wire distribution is a common system for

power loads in commercial and industrial buildings. In such cases, service to the premises is made at 240 volts, 3-phase. Feeders carry the power to panelboards or wireways supplying branch circuits for motor loads. Lighting loads are usually handled by a separate single-phase service to the building. This system offers economic application where the power load is large compared to the lighting load. In some 240-volt, 3-phase, 3-wire systems, a grounded center tap on one of the phases is used as a neutral to provide 120 volts for lighting and receptacle circuits.

4. 480-volt, 3-phase, 3-wire distribution is commonly used in commercial and industrial buildings with substantial motor loads. Service to the building may be made at this voltage, and the 480-volt feeders carried to motor loads and to step-down transformers for lighting and receptacle circuits. In many cases, 480-volt feeders will be derived from load-center substations within the building and carried to motor loads or power panels.

5. 480Y/277-volt, 3-phase, 4-wire distribution has become an important system for use in commercial buildings and industrial buildings. In office and other commercial buildings, the 480-volt, 3-phase, 4-wire feeders are carried to each floor where 480-volt, 3-phase power is tapped to a power panel or to motors; general area fluorescent lighting using 277-volt ballasts is connected between each phase leg and the neutral; and 120/208-volt, 3-phase, 4-wire circuits are derived from step-down transformers for local lighting, appliance and receptacle circuits. Application of this system offers economic advantage over a 120/208-volt system when less than about half of the load devices require 120- or 208-volt power. Where the 480Y system can be used, it will cost less than the 120/208-volt system due to copper savings through the use of smaller sizes of conductors and lower cost of system elements due to lower current capacities. If the required amount of 120- or 208-volt power is over half of the total load in a building, the cost of the step-down transformers to supply these circuits will offset the savings in the 480-volt circuiting. The 480Y system is more advantageous in multi-floor buildings than in buildings of only a few floors or only one floor.

6. 2400-volt, 3-phase distribution is an industrial type system used to feed heavy motor loads directly and motor and lighting loads through load center substations and lighting transformers.

7. 4160Y/2400-volt, 3-phase, 4-wire distribution with a grounded neutral is a more common industrial system than the above 2400-volt, delta-connected system. This system is widely used to supply load center substations in which the voltage is stepped to 480 to feed motors and lighting transformers for 120/240-volt and/or 120/208-volt circuits. It may also be used in distribution to substations stepping the voltage directly to 120/208.

8. 4800-volt 3-phase distribution is a delta-connected industrial system for feeding 480-volt substations supplying motors and lighting transformers.

9. 7200-volt 3-phase distribution is another industrial system used with substations for stepping voltage to lower levels for power and lighting.

10. 13.2Y/7.2-kv (or 13.8 kv) 3-phase, 4-wire distribution is a modern, widely used distribution system for large industrial plants. Power at this voltage is delivered to substations which step the voltage to 480 for motor loads and which supply 480/120-240-volt or 480/120/208-volt transformers for lighting. Or 480Y/277-volt substations may be used to supply motor loads and 277-volt fluorescent or mercury vapor lighting for office and industrial areas. Lighting transformers are then used to supply 120-volt circuits for lighting and convenience receptacles.

The voltage values given for these distribution systems are of course subject to the usual variation or spreads due to distance of transmission and distribution, local conditions of utility supply and settings of transformer taps. In addition to the distribution voltages given, other systems may operate at 6.6 kv, 8.3 kv, 11 kv and 12 kv. Of the high-voltage (over 600 volts) distribution systems, 4160 volts and 13,200 volts are the most common and represent good design selection and economy of application for most cases. In many areas, delta-connected supplies have been changed to 4-wire wye systems with consequent increase in power handling capacity as a result of increased phase to phase voltage. The trend today is toward the use of the 13-kv systems over other high-voltage distribution systems for large industrial plants. To a limited extent, high-voltage distribution finds application in large commercial buildings. The most recent trend in distribution in office and other multi-floor commercial buildings is to distribution at 480Y/277 volts, 3-phase, 4-wire with grounded neutral.

Feeder Requirements

In any electrical system, the "feeders" are the conductors which carry electrical power from the service equipment (or generator switchboard where power is generated on the premises) to the overcurrent protective devices for branch circuits supplying the various loads. In some systems, feeder runs may be made directly from a main switchboard to lighting panels, power panels and/or directly to motor circuits. In other systems, feeders may be carried from a main distribution switchboard to sub-distribution switchboards or panelboards from which subfeeders originate to feed branch circuit panels or motor branch circuits. In still other systems, either or both of the two foregoing feeder layouts may be incorporated with transformer substations to step the distribution voltage to utilization levels. The following discussion covers a detailed analysis of feeder requirements for various types of distribution systems. Because descriptive terms referring to distribution systems and their elements are frequently misused and misunderstood, the following definitions are given to clarify the discussion:

MAINS are the conductors extending from the service switch (or generator or converter bus) to the main distribution center.

FEEDER is a set of conductors originating at a main distribution center and feeding one or more secondary distribution centers, one or more branch circuit dis-

STANDARD LOADS FOR LIGHTING IN COMMERCIAL BUILDINGS

Occupancy	Watts per Sq. Ft.
Armories	
Drill Sheds and Exhibition Halls	5
This does not include lighting circuits for demonstration booths, special exhibit spaces, etc.	
Art Galleries	
a. General	3
b. On Paintings—50 watts per running foot of usable wall area.	
Auditoriums	4
Automobile Show Rooms	6
Banks	
a. Lobby	4
b. Counters—50 watts per running foot including service for signs and small motor applications, etc.	
c. Offices and Cages	5
Barber Shop and Beauty Parlors	5
This does not include circuits for special equipment.	
Billards	
a. General	3
b. Tables—450 watts per table.	
Bowling	
a. Alley Runway and Seats	5
b. Pins—300 watts per set of pins.	
Churches	
a. Auditoriums	2
b. Sunday School Rooms	5
c. Pulpit or Rostrum	5
Club Rooms	
a. Lounge	2
b. Reading Rooms	5
The above two uses are so often combined that the higher figure is advisable. It includes provision for convenience outlets.	
Court Rooms	5
Dance Halls	2
No allowance has been included for spectacular lighting, spots, etc.	
Drafting Rooms	7
Fire Engine Houses	2
Gymnasiums	
a. Main Floor	5
b. Shower Rooms	2
c. Locker Rooms	2
d. Fencing, Boxing, etc.	5
e. Handball, Squash, etc.	5
Halls and Interior Passageways—20 watts per running foot.	
Hospitals	
a. Lobby, Reception Room	3
b. Corridors—20 watts per running foot.	
c. Wards	3
Including allowance for convenience outlets for local illumination.	
d. Private Rooms	5
Including allowance for convenience outlets for local illumination.	
e. Operating Room	5
f. Operating Tables or Chairs	
Major Surgeries—3000 watts per area.	
Minor Surgeries—1500 watts per area.	
This and the above figure include allowance for directional control. Special wiring for emergency systems must also be considered.	
g. Laboratories	5
Hotels.	
a. Lobby	5
Not including provision for conventions, exhibits.	
b. Dining Room	4
c. Kitchen	5
d. Bed Rooms	3
Including allowance for convenience outlets.	
e. Corridors—20 watts per running foot.	
f. Writing Room	5
Including allowance for convenience outlets.	
Library	
a. Reading Rooms	6
This includes allowance for convenience outlets.	
b. Stack Room—12 watts per running foot of facing stacks.	
Motion Picture Houses and Theatres	
a. Auditoriums	2
b. Foyer	3
c. Lobby	5
Museums	
a. General	3
b. Special exhibits—supplementary lighting	5
Office Buildings	
a. Private Offices, no close work	4
b. Private Offices, with close work	5
c. General Offices, no close work	4
d. General Offices, with close work	5
e. File Room, Vault, etc.	3
f. Reception Room	2
Post Office	
a. Lobby	3
b. Sorting, Mailing, etc.	5
c. Storage, File Room, etc	3
Professional Offices	
a. Waiting Rooms	3
b. Consultation Rooms	5
c. Operating Offices	7
d. Dental Chairs—600 watts per chair.	
Railway	
a. Depot—Waiting Room	3
b. Ticket Offices—General	5
On Counters 50 watts per running foot.	
c. Rest Room, Smoking Room	3
d. Baggage, Checking Office	3
e. Baggage Storage	2
f. Concourse	2
g. Train Platform	2
Restaurants, Lunch Rooms and Cafeterias	
a. Dining Areas	3
b. Food Displays—50 watts per running foot of counter (including service aisle.)	
Schools	
a. Auditoriums	3
If to be used as a study hall—5 watts per sq. ft.	
b. Class and Study Rooms	5
c. Drawing Room	7
d. Laboratories	5
e. Manual Training	5
f. Sewing Room	7
g. Sight Saving Classes	7
Show Cases—25 watts per running foot.	
Show Windows	
a. *Large Cities	
Brightly Lighted District—700 watts per running foot of glass.	
Secondary Business Locations—500 watts per running foot of glass.	
Neighborhood Stores—250 watts per running foot of glass.	
b. *Medium Cities	
Brightly Lighted District—500 watts per running foot of glass.	
Neighborhood Stores—250 watts per running foot of glass frontage.	
c. *Small Cities and Towns—300 watts per running foot of glass frontage.	
d. Lighting to Reduce Daylight Window Reflections—1000 watts per running foot of glass.	
Stores, Large Department and Specialty	
a. Main Floor	6
b. Other Floors	6
Stores in Outlying Districts	5
Wall Cases—25 watts per running foot.	

*Wattages shown are for white light with incandescent filament lamps. Where color is to be used, wattages should be doubled.

NOTE: Figures based on use of fluorescent equipment for large-area application, incandescent for local or supplementary lighting.

tribution centers, one or more branch circuits (as in the case of plug-in busway or motor circuit taps to a feeder) or a combination of these.

LIGHTING FEEDER is a feeder to a load which is primarily made up of lighting circuits.

POWER FEEDER is a feeder to a load of motor and/or heating or power branch circuits.

SUBFEEDER is a set of conductors originating at a distribution center other than the main distribution center and supplying one or more branch circuit panelboards or branch circuits.

SWITCHBOARD is a large single panel, frame or assembly of panels, with switches, overcurrent and other protective devices and usually instruments mounted on the front and/or the back. Switchboards are generally accessible from the back as well as from the front and are not intended to be installed in cabinets.

PANELBOARD is a single panel or group of panel units assembled in the form of a single panel. It contains buses tapped by fuse holders, with or without switches, or by circuit breakers, providing protection and, if switches or circuit breakers are used, switch control of circuits for light, heat or power. These circuits may be branch circuits or subfeeders. A panelboard is designed to be placed in a cabinet or cutout box placed in or against a wall or partition and accessible only from the front.

CODE TABLE ON GENERAL LIGHTING UNIT LOADS AND DEMAND FACTORS

Type of Occupancy	COL. A Unit Load Per Sq Ft (Watts)	COL. B. Load to which Demand Factor Applies (Watts)	Demand Factor
Armories and Auditoriums	1	Total Wattage	100%
Banks	2	Total Wattage	100%
Barber Shops and Beauty Parlors	3	Total Wattage	100%
Churches	1	Total Wattage	100%
Clubs	2*	Total Wattage	100%
Court Rooms	2	Total Wattage	100%
Dwellings — (Other Than Hotels)	3*	3,000 or less Next 117,000 Over 120,000	100% 35% 25%
Garages — Commercial (Storage)	½	Total Wattage	100%
Hospitals	2	50,000 or less Over 50,000	40%† 20%
Hotels, including apartment houses without provisions for cooking by tenants	2*	20,000 or less Next 80,000 Over 100,000	50%† 40% 30%
Industrial Commercial (Loft) Buildings	2	Total Wattage	100%
Lodge Rooms	1½	Total Wattage	100%
Office Buildings	3	30,000 or less Over 30,000	100% 70%
Restaurants	2	Total Wattage	100%
Schools	3	Total Wattage	100%
Stores	3	Total Wattage	100%
Warehouses Storage	¼	12,500 or less Over 12,500	100% 50%
In any of above occupancies except single-family dwellings and individual apartments of multi-family dwellings:			
Assembly Halls and Auditoriums	1	Total Wattage as specified for the specific occupancy	
Halls, Corridors, Closets	½		
Storage spaces	¼		

†For sub-feeders to areas in hospitals and hotels where entire lighting is likely to be used at one time, as in operating rooms, ballrooms, dining rooms, etc., a demand factor of 100% shall be used.

***Small Appliances.** The small appliance load specified in sub-paragraph c-1, and the computed branch circuit load for receptacle outlets in other than dwelling occupancies, for which the allowance is not more than 1½ amps per outlet, may be included with the general lighting load and subject to the demand factors in paragraph a of this section.

NOTE:

The figures in this table are bare minimum, at 100% pf. No provision for load growth is made in these values.

Minimum Sizing of Feeders

Feeders and subfeeders are sized to provide sufficient power to the circuits they supply. Selection of the size of a feeder depends upon the size and nature of the known load computed from branch circuit data, the anticipated future load requirements and voltage drop. This represents one of the most important engineering tasks in electrical design work. Economy and efficiency of system operation and maintenance depend heavily on the selection of the proper size of feeders.

Experience with today's electrical modernization work has revealed feeder capacity as the big bottleneck in rewiring old buildings and even some that are not so old. In those buildings, the cost of bringing the capacity of the electrical systems up to meet modern load requirements would be considerably less if original design of feeders had been based on sound study of known and anticipated future loads. All of this experience confirms the importance of careful sizing of feeders, utilizing calculations related to the particular conditions of the job and not just a mechanical procedure of adding up load watts and dividing by volts to get required current carrying capacity.

According to the code, feeders are sized to carry a computed load which is not less than the sum of all branch circuit loads supplied by each feeder, with certain qualifications:

For general illumination, a feeder must have capacity to carry

CURRENT RATINGS OF CONDUCTORS CODE TABLES 1 AND 2

TABLE 1 — ALLOWABLE CURRENT-CARRYING CAPACITIES OF INSULATED CONDUCTORS IN AMPERES

Not More than Three Conductors in Raceway or Cable or Direct Burial
(Based on Room Temperature of 30 C. 86 F.)

Size AWG MCM	Rubber Type R Type RW Type RU Type RUW (14-2) / Type RH-RW / Thermoplastic Type T Type TW	Rubber Type RH / Type RH-RW / Type RHW	Paper / Thermoplastic Asbestos Type TA / Var-Cam Type V / Asbestos Var-Cam Type AVB / MI Cable	Asbestos Var-Cam Type AVA Type AVL	Impregnated Asbestos Type AI (14-8) Type AIA	Asbestos Type A (14-8) Type AA
14	15	15	25	30	30	30
12	20	20	30	35	40	40
10	30	30	40	45	50	55
8	40	45	50	60	65	70
6	55	65	70	80	85	95
4	70	85	90	105	115	120
3	80	100	105	120	130	145
2	95	115	120	135	145	165
1	110	130	140	160	170	190
0	125	150	155	190	200	225
00	145	175	185	215	230	250
000	165	200	210	245	265	285
0000	195	230	235	275	310	340
250	215	255	270	315	335	...
300	240	285	300	345	380	...
350	260	310	325	390	420	...
400	280	335	360	420	450	...
500	320	380	405	470	500	...
600	355	420	455	525	545	...
700	385	460	490	560	600	...
750	400	475	500	580	620	...
800	410	490	515	600	640	...
900	435	520	555	...	...	...
1000	455	545	585	680	730	...
1250	495	590	645	...	...	...
1500	520	625	700	785	...	...
1750	545	650	735	...	...	...
2000	560	665	775	840	...	...

CORRECTION FACTORS FOR ROOM TEMPERATURES OVER 30 C. 86 F.

C. F.						
40 104	.82	.88	.90	.94	.95	...
45 113	.71	.82	.85	.90	.92	...
50 122	.58	.75	.80	.87	.89	...
55 131	.41	.67	.74	.83	.86	...
60 140	...	.58	.67	.79	.83	.91
70 158	...	.35	.52	.71	.76	.87
75 167	...	...	.43	.66	.72	.86
80 176	...	...	.30	.61	.69	.84
90 194	...	...	...	.50	.61	.80
100 212	...	...	...	...	.51	.77
120 248	...	...	...	...	...	.69
140 284	...	...	...	...	...	.59

TABLE 2 — ALLOWABLE CURRENT-CARRYING CAPACITIES OF INSULATED CONDUCTORS IN AMPERES

Single Conductor in Free Air
(Based on Room Temperature of 30 C. 86 F.)

Size AWG MCM	Rubber Type RW Type RU Type RUW (14-2) / Type RH-RW / Thermoplastic Type T Type TW	Rubber Type RH / Type RH-RW / Type RHW	Thermoplastic Asbestos Type TA / Var-Cam Type V / Asbestos Var-Cam Type AVB / MI Cable	Asbestos Var-Cam Type AVA Type AVL	Impregnated Asbestos Type AI (14-8) Type AIA	Asbestos Type A (14-8) Type AA	Slow-burning Type SB / Weatherproof Type WP Type SBW
14	20	20	30	40	40	45	30
12	25	25	40	50	50	55	40
10	40	40	55	65	70	75	55
8	55	65	70	85	90	100	70
6	80	95	100	120	125	135	100
4	105	125	135	160	170	180	130
3	120	145	155	180	195	210	150
2	140	170	180	210	225	240	175
1	165	195	210	245	265	280	205
0	195	230	245	285	305	325	235
00	225	265	285	330	355	370	275
000	260	310	330	385	410	430	320
0000	300	360	385	445	475	510	370
250	340	405	425	495	530	...	410
300	375	445	480	555	590	...	460
350	420	505	530	610	655	...	510
400	455	545	575	665	710	...	555
500	515	620	660	765	815	...	630
600	575	690	740	855	910	...	710
700	630	755	815	940	1005	...	780
750	655	785	845	980	1045	...	810
800	680	815	880	1020	1085	...	845
900	730	870	940	....	....	...	905
1000	780	935	1000	1165	1240	...	965
1250	890	1065	1130	....	....	...	....
1500	980	1175	1260	1450	....	...	1215
1750	1070	1280	1370	....	....	...	....
2000	1155	1385	1470	1715	....	...	1405

CORRECTION FACTORS FOR ROOM TEMPERATURES OVER 30 C. 86 F.

C. F.							
40 104	.82	.88	.90	.94	.95	...	....
45 113	.71	.82	.85	.90	.92	...	....
50 122	.58	.75	.80	.87	.89	...	....
55 131	.41	.67	.74	.83	.86	...	....
60 140	...	.58	.67	.79	.83	.91	....
70 158	...	.35	.52	.71	.76	.87	....
75 167	...	...	.43	.66	.72	.86	....
80 176	...	...	.30	.61	.69	.84	....
90 194	...	...	....	.50	.61	.80	....
100 212	...	...	....	...	.51	.77	....
120 248	...	...	....	...	...	.69	....
140 284	...	...	....	...	...	.59	....

Feeder Loads for Air Conditioning

Type of Building	Watts per Square Foot of Floor Area of Conditioned Space		
	Low	Average	High
Banks	4	5	7
Department Stores			
Basement	4	5	10
Main Floor	5	7	12
Upper Floors	3	4	6
Hotel Guest Rooms (per room)	1	1.5	2
Office Buildings	3	4	6
Office Suites	3	3.5	5
Stores	2 to 6	4 to 7	5 to 10
Restaurants	10	15	20
Theatres (per seat)	65	75	80

Basic Formula for Calculating Required Feeder Carrying Capacity

$$I = \frac{\text{Load Watts}}{K \times E \times PF} = \frac{\text{Load Volt-Amperes}}{K \times E}$$

K = 1 for 2-wire dc or single-phase ac
= 1.73 for 3-wire, 3-phase ac
= 2 for 3-wire dc or single-phase ac
= 3 for 4-wire, 3-phase ac

E = voltage between outside wire and neutral or, if no neutral exists, between any two line wires (volts)

I = current in any line wire except neutral (amperes), which feeder must be rated to carry (check tables of conductor current ratings)

the total load of lighting branch circuits determined as part of the lighting design or a minimum branch circuit load determined on a watts-per-square-foot basis from the table given in section 2203 of the code. The demand factors given in the last column of this table may be applied to the total branch circuit load to get required feeder capacity for lighting.

If show-window lighting is supplied by the feeder, capacity must be included in the feeder to handle 200 watts for each linear foot of show-window length.

In single family dwellings, in individual apartments of multi-family dwellings with provisions for cooking by tenants or in a hotel suite with a serving pantry, at least 1500 watts, to handle the small appliance load in kitchen and dining areas, must be added to the general lighting load, subject to the demand factors given in the unit-load table.

In other than dwelling occupancies, the branch circuit load for receptacle outlets for which not more than 1½ amps were allowed per outlet may be added to the general lighting load, subject to the demand factors.

Feeder capacity must be allowed for electric cooking appliances, rated over 1¾ kw, in accordance with Table 29 in Chapter 10 of the code. In most cases, the feeder must have a capacity of 8000 watts for a single electric range.

For fixed appliances other than ranges and space heating equipment, feeder capacity must be provided for the sum of these loads and the total load of four or more such appliances may be reduced by a demand factor of 75%. From the total load represented by the foregoing particular loads, the required size of feeder conductors is determined by dividing the total load in watts by the voltage between the hot leg and the neutral in the case of a 2-wire feeder, by the voltage between the two hot legs in the case of a 3-wire, single-phase feeder or by the square root of three, times the voltage between two phase legs in the case of 3-wire or 4-wire, 3-phase feeders from either a wye- or delta-connected source. If power factor is other than unity, it should be included in the denominator in all of these calculations.

If motor loads are supplied by a feeder which also supplies lighting and appliance loads as described above, Article 430 of the code (sections 4314, 4315 and 4316) gives the required capacity which the feeder must include to handle such loads. Feeders to motor loads are covered in detail later on in this section. Capacity of a feeder supplying fixed electrical space heating equipment is determined on the basis of a load equal to the total connected load on all branch circuits served from the feeder. Under conditions of intermittent operation or where all units cannot operate at the same time, permission may be granted for use of less than 100% demand factor in sizing the feeder.

It should be noted that all of the foregoing are general requirements of the code and cover minimum load conditions. This is particularly true of the unit loads of watts-per-square-foot, given in the table, which are based on 100% power factor. And determination of feeder size solely on the basis of code requirements provides no relation to particular operating conditions in an occupancy or any allowance for future growth in the load served by the feeder. Although there are certain feeder applications which can be satisfactorily sized by use of the indicated code method of sizing, modern feeder design practice carefully incorporates such factors as voltage drop, power factor, detailed analysis of watts-per-square-foot loads, realistic and studied application of demand factors and provision of substantial spare capacity as required in each case.

Adding Circuit Loads

In the section on "Branch Circuits," procedures were given for determining various types of branch circuit loads—general lighting, local lighting, fixed appliance, special receptacle circuits and general-use convenience receptacles—and for determining the number of circuits to handle the loads. Whether general lighting circuits were determined on a watts-per-square-foot basis or from a lighting design layout, the amount of load for general illumination is known, and capacity for this load must be designed into the feeder, modified by the applicable demand factor from the table in section 2203. Other circuit loads—such as local and/or special lighting, motor loads, electric cooking appliances and fixed appliances—are also generally known loads and can be accounted for in a feeder. Loads for convenience receptacle circuits and spare circuits in the panelboard, however, are not known and must be estimated in sizing a feeder. From the known and estimated loads, the initial feeder load to a panelboard can be determined as follows:

1. For each multi-outlet branch circuit supplying general lighting, allow watts equal to the load on

the circuit. If 50% loading of circuits is used, as recommended, allow 900 watts for each 2-wire, 120-volt 15-amp circuit; 1200 watts for each 2-wire, 120-volt 20-amp circuit; 1800 watts for each 2-wire, 120-volt 30-amp circuit; 2100 watts for each 2-wire, 277-volt 15-amp circuit; 2800 watts for each 2-wire, 277-volt 20-amp circuit; 4200 watts for each 2-wire, 277-volt 30-amp circuit.

2. For each multi-outlet plug receptacle branch circuit, allow watts equal to half the watts rating of the circuit, if such circuits were loaded to 50% of capacity, or allow watts equal to the load value of such circuits as used in branch circuit design. The minimum watts allowance for each receptacle circuit must equal the number of outlets times 1½ amps, times 120 volts.

3. For each multi-outlet branch circuit supplying heavy-duty lampholders, allow watts equal to the load on the circuit as used in branch circuit design. The minimum watts allowance for each heavy-duty circuit must equal the number of outlets times 5 amps, times the circuit volts.

4. For each multi-outlet branch circuit supplying local or special lighting, allow watts equal to the load on the circuit.

5. For each individual branch circuit supplying a fixed appliance, allow watts equal to the rating of the appliance.

6. For each individual branch circuit supplying an electric cooking appliance, allow watts equal to the watts given in Table 29 in Chapter 10 of the code for the particular size of cooking appliance.

7. For each individual branch circuit supplying a motor, allow watts equal to 1.25 times the motor full-load current (from code Tables 21 to 24 according to the horsepower of the motor), times the circuit voltage. For 3-phase motors, the foregoing product must be multiplied by 1.732 to get the correct watts. Actually, the result of these calculations is not a watts value but a volt-ampere product, due to the lower-than-unity power factor of the motor.

8. For each branch circuit supplying more than one motor, allow watts equal to the following product: take 1.25 times the full-load current rating of the highest rated motor; add to this the sum of the full-load current ratings of the other motors; then multiply the total sum by the circuit volts. Again, this product must be multiplied by 1.732 to get the correct volt-ampere product for 3-phase motors.

9. For each spare branch circuit provided in the panelboard, allow watts equal to the values given above for multi-outlet general lighting branch circuits (See foregoing par. 1).

Initial Feeder Load

By adding up these ratings, total watts is obtained which is the initial feeder load. Of course, the majority of feeders used in commercial, institutional and industrial buildings will serve only a few of the above described loads. And feeders in different buildings will handle different combinations of loads. Although the table in section 2203 allows limited use of demand factors for general lighting circuits and multi-outlet plug receptacle circuits, reducing the feeder design load, most occupancies require a demand factor of 100% applied to the total load obtained by adding up the circuit loads.

The total load obtained above represents only the present provision for branch circuit loads. Future utilization of the spare capacity designed into the branch circuits (they are loaded only to 50%) has not yet been accounted for in the feeder. And no provision has been designed into the feeder to meet the future possibility of exceeding the maximum capacity of the panelboard itself. Certainly, in the light of present experience with electrical modernization, there are many cases in which a little forethought and study would reveal the advisability of making such a provision in feeder capacity. Not in all cases, or even in most cases, but there is such a possibility; and only careful consideration of the nature of electrical utilization in a particular occupancy will accurately indicate possible future load requirements. But certainly in all cases of electrical design, some spare capacity must be provided in the feeders.

Allowance for load growth in feeders should begin with the spare capacity designed into the branch circuits. For all circuits loaded to 50% of capacity, it can be assumed that there is an allowance for growth of each circuit load by an amount equal to 30% of the circuit capacity. This allowance is based on the code limitation of 80% load on circuits which are in operation for long periods of time or on circuits which supply motor-operated appliances in addition to other appliances and/or lighting. The 30% growth allowance in each circuit should be converted to total watts figure and added to the total load on the feeder as calculated above. This grand total then represents the required feeder capacity to handle the full circuit load on the panelboard. The next step is to provide capacity in the feeder for anticipated load growth (plus some amount for possible unforeseen future requirements).

Spare Feeder Capacity

From experience, modern design practice dictates the sizing of feeders to allow increase of at least 50% in load on a feeder where analysis reveals any load growth possibilities. Such analysis depends upon the type of building, the work performed, the plans or expectations of management with respect to expansion of facilities or growth of business, the type of distribution system used, locations of centers of loads, permanence of various load conditions and particular economic conditions. Depending upon thorough study of all of these factors, the advisability of spare capacity can be determined for each feeder in a distribution system. But where study demands extra capacity in a feeder, substantial growth allowance—50%—is generally essential to realize the sought-after economy of future electrical expansion. Skimpy upsizing of feeder conductors or raceways has proved a major shortcoming of past electrical design work. This is particularly true in tall

Aluminum Conductors

The use of aluminum cables for feeders (in the larger sizes of cables) can often effect substantial economies in material and installation costs. Note 1 to Table 1 of the National Electrical Code comments on the sizing of aluminum conductors as follows:

"For aluminum conductors, the allowable current-carrying capacities shall be taken as 84% of those given in the table for the respective sizes of copper conductor with the same kind of insulation."

GENERAL DATA FOR CALCULATIONS

DC CIRCUIT CHARACTERISTICS

Ohm's Law:

$$E = IR \qquad I = \frac{E}{R} \qquad R = \frac{E}{I}$$

E = voltage impressed on circuit (volts)
I = current flowing in circuit (amperes)
R = circuit resistance (ohms)

In direct current circuits, electrical power is equal to the product of the voltage and current:

$$P = EI = I^2R = \frac{E^2}{R}$$

P = power (watts)
E = voltage (volts)
I = current (amperes)
R = resistance (ohms)

AC CIRCUIT CHARACTERISTICS

The instantaneous values of an alternating current or voltage vary from zero to a maximum value each half cycle. In the practical formulae which follow, the "effective value" of current and voltage is used, defined as follows:

Effective value = 0.707 × maximum instantaneous value

Impedance:

Impedance is the total opposition to the flow of alternating current. It is a function of resistance, capacitive reactance and inductive reactance. The following formulae relate these circuit properties:

$$X_L = 2\pi fL \qquad X_C = \frac{1}{2\pi fC} \qquad Z = \sqrt{R^2 + (X_L - X_C)^2}$$

X_L = inductive reactance (ohms)
X_C = capacitive reactance (ohms)
Z = impedance (ohms)
f = frequency (cyles per second)
C = capacitance (farads)
L = inductance (henrys)
R = resistance (ohms)
π = 3.14

Ohm's Law for AC Circuits:

$$E = I \times Z \qquad I = \frac{E}{Z} \qquad Z = \frac{E}{I}$$

POWER FACTOR

Power factor of a circuit or system is the ratio of actual power (watts) to apparent power (volt-amperes), and is equal to the cosine of the phase angle of the circuit:

$$PF = \frac{\text{actual power}}{\text{apparent power}} = \frac{\text{watts}}{\text{volts} \times \text{amperes}} = \frac{KW}{KVA} = \frac{R}{Z}$$

KW = kilowatts
KVA = kilovolt-amperes = volt-amperes × 1,000
PF = power factor (expressed as decimal)

SINGLE-PHASE CIRCUITS

$$KVA = \frac{EI}{1{,}000} = \frac{KW}{PF} \qquad KW = KVA \times PF$$

$$I = \frac{P}{E \times PF} \qquad E = \frac{P}{I \times PF} \qquad PF = \frac{P}{E \times I}$$

$P = E \times I \times PF$
P = power (watts)

THREE-PHASE CIRCUITS, BALANCED STAR OR WYE

$$I_N = 0 \qquad I = I_p \qquad E = \sqrt{3}\,E_p = 1.73\,E_p$$

$$E_p = \frac{E}{\sqrt{3}} = \frac{E}{1.73} = 0.577E$$

I_N = current in neutral (amperes)
I = line current per phase (amperes)
I_p = current in each phase winding (amperes)
E = voltage, phase to phase (volts)
E_p = voltage, phase to neutral (volts)

THREE-PHASE CIRCUITS, BALANCED DELTA

$$I = 1.732 \times I_p \qquad I_p = \frac{I}{\sqrt{3}} = 0.577 \times I$$

$E = E_p$

POWER: BALANCED 3-WIRE, 3-PHASE CIRCUIT, DELTA OR WYE

For unity power factor (PF = 1.0):

$P = 1.732 \times E \times I$

$$I = \frac{P}{\sqrt{3}\,E} = \frac{0.577P}{E} \qquad E = \frac{P}{\sqrt{3} \times I} = \frac{0.577P}{I}$$

P = total power (watts)

For any load:

$$P = 1.732 \times E \times I \times PF \qquad VA = 1.732 \times E \times I$$

$$E = \frac{P}{PF \times 1.73 \times I} = \frac{0.577 \times P}{PF \times I}$$

$$I = \frac{P}{PF \times 1.73 \times E} = \frac{0.577 \times P}{PF \times E}$$

$$PF = \frac{P}{1.73 \times I \times E} = \frac{0.577 \times P}{I \times E}$$

VA = apparent power (volt-amperes)
P = actual power (watts)
E = line voltage (volts) phase to phase
I = line current (amperes)

POWER LOSS: ANY AC OR DC CIRCUIT

$$P = I^2R \qquad I = \sqrt{\frac{P}{R}} \qquad R = \frac{P}{I^2}$$

P = power heat loss in circuit (watts)
I = effective current in conductor (amperes)
R = conductor resistance (ohms)

office buildings, apartment houses and other commercial buildings in which elimination of riser bottlenecks represents a large part of the total modernization cost.

Provision of spare capacity in feeders may be provided in one or more of several ways. If the anticipated increase in feeder load is to be made in the near future, the extra capacity should usually be included in the conductor size and installed as part of the initial electrical system. In many small office or commercial buildings and apartment houses, extra capacity should automatically be included in the initial size of the feeder conductors, provided the size is not greater than No. 2 after adding the 50% of extra capacity. Other methods of providing for growth in feeder load are as follows:

1. Selection of raceways larger than required by the initial size and number of feeder conductors. With this provision, the conductors can be replaced with larger sizes if required at a later date. The advisability of this step should be carefully determined in the case of risers or underground or concealed feeder raceway runs. In some cases, a compromise can be made between providing spare capacity in the feeder conductor size and up-sizing the feeder raceway.

2. Including spare raceways in which conductors may be installed at a later date to obtain capacity for load growth. Such arrangements of multiple raceways must be carefully laid out and related to the existing overall system. The types of feeder distribution centers or main switchboards and the layouts of local branch circuit panelboards must be able to accommodate future expansion of distribution capacity based on the use of spare raceways, with modification and regrouping of feeder loads.

Selecting Conductor Sizes

When total design watts, including all of the foregoing provisions, have been determined, this value is then used with the voltage and other electrical characteristics of the feeder to obtain the required current carrying capacity of the conductors. In addition to circuit voltage, feeder conductor size for a particular total wattage will depend upon the power factor and the voltage drop in the conductors.

An accompanying table covers the necessary calculations for sizing feeders. In these calculations, and in the determination of the feeder design load, care should be taken to distinguish between circuit load values in "watts" and those in "volt-amperes". When load values are in watts, power factor must be taken into consideration. Load values in volt-amperes do not have to be adjusted by the power factor in sizing feeder conductors. The size of conductors is related to total current values and must have capacity to carry the current at the given value of power factor. Of course, at low power factor, the conductors must have more current-carrying capacity to supply a particular load wattage than they would have to have at high power factor.

Voltage drop must be carefully considered in sizing feeder conductors. According to the National Electrical Code, size of feeder conductors must be such that voltage drop up to the branch circuit panelboards or point of branch circuit origin is not more than 3% for power or heating loads and not more than 1% for lighting loads or combined lighting, heating and power loads. Local codes may impose lower limits of voltage drop. Design practice finds 1% for lighting loads and 2% for power loads as accepted voltage drop maximums. Calculation of voltage drop in any set of feeders is described in an accompanying table. From this calculation, it can be determined if the conductor size initially selected to handle the load will be adequate to maintain voltage drop within given limits. If it is not, the size of the conductors must be increased until the voltage drop is within prescribed limits.

Feeder Neutral Load

Section 2203-g of the code covers requirements for sizing the neutral conductor in a feeder. It states that "the neutral feeder load shall be the maximum unbalance" of the feeder load. "The maximum unbalanced load shall be the maximum connected load between the neutral and any one ungrounded conductor. . . ." In a 3-wire, 120-240-volt, single-phase feeder, the neutral must have a current carrying capacity at least equal to the current drawn by the total 120-volt load connected between the more heavily loaded hot leg and the neutral. It should be noted that straight 240-volt loads, connected between the two hot legs, do not place any load on the neutral. As a result, the neutral conductor of such a feeder must be sized to make up a 2-wire 120-volt circuit with the more heavily loaded hot leg. Actually, the 120-volt circuit loads on such a feeder would be balanced on both sides of the neutral which would be the same size as each of the hot legs if only 120-volt loads were supplied by the feeder. If 240-volt loads were also supplied, the hot legs would be sized for the total load and the neutral for only 120-volt loads.

Section 2203-g contains two other conditions for sizing neutral conductors. The first of these refers to electric range loads of feeders and the second refers to feeders of three or more wires. When a feeder supplies electric ranges, the neutral conductor must have a carrying capacity at least equal to 70% of the current capacity required in the ungrounded conductors to handle the load. Table 29 in Chapter 10 of the code gives the demand loads to be used in sizing feeders which supply electric ranges and other cooking appliances. For feeders of three or more conductors—3-wire, dc; 3-wire, single-phase; and 4-wire, 3-phase —a further demand factor of 70% may be applied to that portion of the unbalanced load in excess of 200 amps. That is, in a feeder supplying only 120-volt loads evenly divided between each ungrounded conductor and the neutral, the neutral conductor must be the same size as each ungrounded conductor up to 200 amps capacity, but may be reduced from the size of the ungrounded conductors for loads above 200 amps by adding to the 200 amps only 70% of the amount of load current above 200 amps in computing the size of the neutral. It should be noted that this 70% demand factor is applicable to the *unbalanced load* in excess of 200 amps and not simply to the total load, which in many cases may be made up of balanced 240-volt loads or straight 3-phase loads. Determination of required neutral current carrying capacity can often be facilitated by vector analysis of the particular conditions involved.

Another frequently discussed code requirement is that of section 2204, covering the use of a common neutral with more than one

Fundamentals of Voltage Drop and Copper Loss

Unity Load Power Factor, Negligible Reactance in Conductors

where E = circuit voltage

R_1 = total resistance of circuit conductors

R_2 = resistance of non-inductive (unity pf) load

I = circuit current

$$I = \frac{E}{R_1 + R_2} = \frac{200}{2 + 18} = 10 \text{ amps}$$

Voltage drop in conductors $= I \times R_1 =$

$10 \times 2 = 20$ volts

Copper loss in conductors $= I^2 \times R_1 =$

$(10)^2 \times 2 =$

$100 \times 2 = 200$ watts

$$\% \text{ Voltage drop} = \frac{20}{200} = 10\%$$

Voltage delivered to load = 200-20 = 180 volts

Wattage delivered to load $= I^2 \times R_2 = 100 \times 18 = 1800$ watts

PF = 100%

When the load power factor is unity and the conductor reactance due to self-induction is negligible, calculation of voltage drop in the circuit and copper loss due to heating effect of current in the conductors follows the standard relations between current and voltage. The supply voltage is equal to the arithmetic sum of the voltage drop in the conductors and the voltage across the load. Copper loss in watts is a straight "I-squared R" loss.

Less Than Unity Power Factor of Load, Negligible Reactance in Conductors

where E = circuit voltage

R_1 = total resistance of circuit conductors

R_2 = resistive component of load

X_L = reactive component of load

Z = impedance of load

I = circuit current

$Z = \sqrt{(R_2)^2 + (X_L)^2}$

$Z^2 = (R_2)^2 + (X_L)^2$

$(20)^2 = 400 = (R_2)^2 + (X_L)^2$

but, pf $= 0.8 = \frac{R_2}{Z}$

then, $R_2 = 20 \times 0.8 = 16$ ohms

and, $(X_L)^2 = 400 - (16)^2 = 144$

$X_L = 12$ ohms

Total Z of circuit $= \sqrt{(R_1 + R_2)^2 + (X_L)^2}$

$= \sqrt{(18)^2 + (12)^2}$

$=$ 21.6 ohms

then, $I = \frac{200v}{21.6} = 9.3$ amps

Voltage drop in conductors $= I \times R_1 =$

$9.3 \times 2 = 18.6$ volts

Copper loss in conductors $= I^2 \times R_1 =$

$86.5 \times 2 = 173$ watts

Apparent % voltage drop $= \frac{18.6}{200} = 9.3\%$

Voltage delivered to load $= I \times Z = 9.3 \times 20 = 186$ volts

Significant % voltage drop $= \frac{14}{200} = 7\%$

PF < 100%

When the load power factor is less than unity and the conductor reactance is negligible, the straight arithmetic relations among the circuit conditions no longer obtain. It should be noted that although a conductor voltage drop of 18.6 volts exists, the load voltage is equal to 9.3 amps times 20 ohms or 186 volts. The real loss (or drop) in voltage to the load is only 14 volts (200 volts minus 186 volts). The 18.6-volt drop is only the voltage across the resistive conductor load, which differs in phase from the voltage across the reactive load device fed by the circuit. Although the arithmetic sum of the two voltages is 204.6 volts (186 volts plus 18.6 volts), correct vectorial addition of the two voltages gives the 200-volt value of the supply. The significant percent voltage drop is therefore different from the apparent value. Copper loss, however, remains a simple "I-squared R" loss.

(Values used in these examples were assumed and chosen to make simple calculations)

Standard Calculations for Voltage Drop With Negligible Conductor Reactance

Two-Wire DC Circuits:

$$V = \frac{2k \times L \times I}{d^2} = 2R \times L \times I \qquad d^2 = \frac{2k \times I \times L}{V}$$

V = drop in circuit voltage (volts)
R = resistance per foot of conductor (ohms/foot)
I = current in conductor (amperes)
L = one-way length of circuit (feet)
d^2 = cross-section area of conductor (circular mils)
k = resistivity of conductor metal (cir. mil-ohms/ft) (k = 12 for circuits loaded to more than 50% of allowable carrying capacity; k = 11 for circuits loaded less than 50%.)

Three-Wire DC Circuits:

$$V = \frac{2k \times L \times I}{d^2} \qquad V_n = \frac{V}{2}$$

V = drop between outside conductors (volts)
V_n = drop between one outside conductor and neutral (volts)
I = current in more heavily loaded outside conductor (amperes)
L = one-way length of circuit (feet)
d^2 = cross-section area of conductor (circular mils)
k = resistivity of conductor metal (cir. mil-ohms/ft) (Use same values of k as in 2-wire circuits above.)

Two-Wire, Single-Phase Circuits: (Inductance Negligible)
Same calculations as for 2-wire dc circuit.

Three-Wire, Single-Phase Circuits: (Inductance Negligible)
Same calculations as for 3-wire dc circuits.

Three-Wire, Three-Phase Circuits: (Inductance Negligible)
Same calculations as for 2-wire dc circuit carrying the same current, multiplied by 0.866:

$$V = \frac{2k \times I \times L}{d^2} \times 0.866$$

V = voltage drop of 3-phase circuit

Four-Wire, Three-Phase Balanced Circuits:
(Inductance Negligible):
For lighting loads: Voltage drop between one outside conductor and neutral equals one-half of drop calculated by formula for 2-wire dc circuits.

For motor loads: Voltage drop between any two outside conductors equals 0.866 times drop determined by formula for 2-wire dc circuits.

(See Voltage Drop Tables in BRANCH CIRCUIT Section)

---

set of feeders. This section says that "A common neutral feeder may be employed for two or three sets of 3-wire feeders, or two sets of 4-wire feeders. . . . " It further states that "When in metal enclosures, all conductors of feeder circuits employing a common neutral feeder shall be contained within the same enclosure. . . ." A common neutral is a single neutral conductor used as the neutral for more than one set of feeder conductors. It must have current carrying capacity equal to the sum of the neutral conductor capacities if an individual neutral conductor were used with each feeder set. A common neutral may be used only with feeders, never with branch circuits.

Motor Feeders

Article 430 of the code covers general requirements for motor feeders. Design of motor feeders must conform to these code requirements and must incorporate considerations of adequacy, flexibility, voltage drop and safety. Basic sizing and protection of feeder conductors involves the following procedures:

1. The current-carrying capacity of feeder conductors supplying several motors must at least be equal to 125% of the full-load current of the highest rated motor plus the sum of the full-load currents of the other motors supplied by the feeder.

2. The current-carrying capacity of feeder conductors supplying a single motor must at least be equal to 125% of the full-load current of the motor.

3. The current-carrying capacity of feeder conductors supplying a motor load and a lighting and/or appliance load must be sufficient to handle the lighting and/or apppliance load as determined from the procedure for calculating size of lighting feeders, plus the motor load as determined from the previous paragraphs.

The code permits use of demand factors for motor feeders—based on reduced heating of conductors supplying motors operating intermittently or on duty-cycle or motors not operating together—when the authority enforcing the code deems the conditions and operating characteristics suitable for reduced capacity feeders.

Voltage Drop

Voltage drop and copper loss must be carefully taken into consideration when sizing motor feeders. The design percentage of tolerable voltage drop may vary with the particular operating conditions and layout of the motor loads served but must never exceed 3% drop from the service entrance to the point of origin of motor branch circuits. However, a maximum voltage drop of only 2% is widely used and recommended for motor feeder design. Calculation of such voltage drop should include consideration of reactance as well as resistance in the feeder conductors, as both contribute to the drop. And power factor must be accounted for in these calculations.

Voltage drop in a feeder must also be analyzed in terms of the number of motors supplied, the size of each motor and the operating duty of each. When a number of motors might be starting simultaneously or several motors driving

sluggish loads might be started at or near the same time, the voltage drop in the feeder could be extreme unless its size accounted for the high load current. Of course, such conditions and analysis of them will often clearly indicate further sub-division or adjustment of feeder loads, selection of types of motors to use—such as wound rotor instead of straight induction to limit starting current—and selection of the best types of controllers to use. The initial value of starting current—the locked-rotor current—must be used in studying the effect of motor loads on voltage drop.

Copper loss in motor feeders—the watts lost in the conductors due to heat developed by current flow through the conductors—equals the square of the total current drawn through the conductors times the total resistance of the conductors. This loss may frequently be substantial even when the voltage drop in the feeder is within recommended limits. For this reason, all voltage drop studies and calculations should include consideration of further increasing conductor size—over that necessary to limit voltage drop—in order to limit copper loss. Power factor is related to these matters as shown in accompanying formulas and calculations. Through all such design work, it should be remembered that the values for motor running currents given in code tables and on nameplates are actual values of current drawn from the line when the prescribed voltage is impressed across the motor terminals. These values, which are used in sizing conductors and other circuit equipment, are also the values used in voltage drop and copper loss calculations and need no adjustment for power factor of the individual motors.

Overcurrent Protection

Overcurrent protection for a feeder to several motors must have a rating or setting not greater than the largest rating or setting of branch circuit protective device for any motor of the group plus the sum of the full-load currents of the other motors supplied by the feeder. If two or more motors of equal horsepower rating are the largest in the group, one of these should be considered as the largest for the calculation of feeder overcurrent protection. It should be noted that, in large capacity installations where extra feeder capacity is provided for load growth or future changes, the feeder overcurrent protection may be calculated on the basis of the rated current-carrying capacity of the feeder conductors. In some cases, such as where two or more motors on a feeder may be started simultaneously, feeder conductors may have to be larger than usually required for feeders to several motors. In such cases, correspondingly larger ratings or settings of feeder overcurrent protection may be used.

Protection for a feeder to both motor loads and a lighting and/or appliance load must be rated on the basis of both of these loads. The rating or setting of the overcurrent device must be sufficient to carry the lighting and/or appliance load plus the rating or setting of the motor branch circuit protective device if only one motor is supplied, or plus the highest rating or setting of branch circuit protective device for any one motor plus the sum of the full-load currents of the other motors if more than one motor is supplied.

Switchboards and Panelboards

In modern buildings, feeder distribution centers provide for protection and control of feeders to various loads. In 3-phase, 4-wire systems, both lighting and power feeders may originate from a single distribution center. In those systems using separate power and light services, a separate distribution center is generally used with each type of feeders. Modern distribution centers for lighting and appliance feeders include dead-front panelboards and dead-front

Calculating Copper Loss in Conductors

Assuming resistivity of conductor metal to be as follows,

K = 12 for circuits loaded to more than 50% of their allowable current-carrying capacity, or

K = 11 for circuits loaded to less than 50% of their allowable current-carrying capacity

the power lost as heat due to flow of current through a conductor may be found from the formula

$$P = \frac{K \times L \times I^2}{CM}$$

in which, P = power lost in the conductor (watts)
K = resistivity of conductor metal (circular mil-ohms/foot)
I = current in the conductor (amperes)
L = length of the conductor (feet)
CM = cross-section area of the conductor in circular mils

For a 2-wire circuit (direct-current or single-phase):

$$P = \frac{2 \times K \times L \times I^2}{CM}$$

For a 3-wire, 3-phase circuit (assuming balanced load):

$$P = \frac{3 \times K \times L \times I^2}{CM}$$

in which, P = power lost in the circuit (watts)
K = resistivity of conductor metal (circular mil-ohms/foot)
I = current in each wire of the circuit (amperes)
L = one-way length of the circuit (feet)
CM = cross-section area of each of the wires in circular mils

When the resistance of conductors is determined from a table, the copper loss is calculated from the relation

$$P = I^2R$$

switchboards. Feeders are tapped through fused switches or circuit breakers from the buses in such distribution centers. Distribution centers are usually supplied by the service or services to buildings and contain the main service switches. This is the most common arrangement in commercial and institutional buildings. In many industrial buildings, feeder distribution centers may be supplied from transformers which step high-voltage distribution to utilization levels.

Selection of suitable panelboards and/or switchboards for feeder distribution is based on many factors. Manufacturers of such equipment offer a wealth of literature and technical data on the characteristics and application advantages of the different types. In selecting feeder disconnect and protection equipment, consideration should be given to spare capacity in this equipment. Depending upon the anticipated future requirements and the manner in which extra capacity was included in the feeders, space should be provided in switchboards and/or feeder panelboards for additional switches or circuit breakers or for future installation of larger switching and protection units. And design of the distribution system must integrate all provisions for future expansion of feeder capacities. This includes the routing of spare feeder conduit, accessibility to feeder raceway in which capacity has been allowed for increase in feeder conductors, ease of connections in the switching and protection assemblies. Construction of modern switchboards and feeder panelboards will accommodate all of these design provisions for load growth. Care in the selection of the proper type of switching and protection assemblies—with buses of substantial capacity for future expansion of the system—is essential to economy of distribution design.

Modern commercial, institutional and industrial buildings generally utilize dead-front switchgear of sectional construction. The assembly may contain fused switches in safety-type unit enclosures or unit circuit breakers. Selection of switchgear will depend upon voltage rating, ampere rating, number of phases and short-circuit rating. Circuit-breaker switchgear may be of the stationary type, in which the breakers are bolted to the bus and frame, or of the draw-out type, in which the breakers are mounted on a slide-out mechanism for easy removal or maintenance, disconnecting the breaker from the bus. Switchboards may be equipped with provisions for instrument transformers and metering. Feeders from the switchboard may be carried directly to lighting or power branch circuit panelboards, to subfeeder distribution switchboards or panelboards, to motor control centers or to individual motor loads.

Feeder distribution panelboards are also made in many sizes and

Multiple Conductors For Feeders

From the code tables of current-carrying capacities of various sizes of conductors, it can be seen that small conductor sizes carry more current per circular mil of cross section than do large conductors. This results from rating conductor capacity according to temperature rise. The larger a cable, the less is the radiating surface per circular mil of cross section. Loss due to "skin effect" (apparent higher resistance of conductors to alternating current than to direct current) is also higher in the larger conductor sizes. And larger conductors cost more per ampere than smaller conductors.

All of the foregoing factors point to the advisability of using a number of smaller conductors in multiple to get a particular carrying capacity, rather than using a single conductor of that capacity. In many cases, multiple conductors for feeders provide distinct operating advantages and are more economical than the equivalent-capacity single-conductor makeup of a feeder.

The following table and data represent one studied approach to the possible merit of multiple conductor power circuits. Any electrical designer can work out such data for his own use.

POWER FEEDER SPECIFICATION DATA

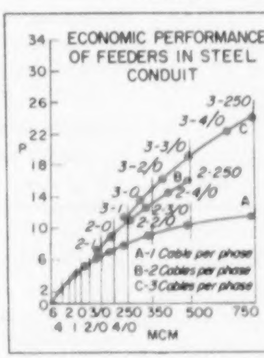
P	Cable Size	Cables Per Phase	Conduit Size	Cost in Dollars Per 100 Feet	Ampere Rating NE Code	Dollars Per 100 Feet Per Unit P	Economic Choice
2.0	4	1	1¼	$136.00	70	$68.00	
3.0	2	1	1¼	151.00	95	50.30	
3.7	1	1	1½	189.00	110	51.10	
4.6	0	1	2	237.00	125	51.50	
5.5	2/0	1	2	260.00	145	47.20	
6.6	3/0	1	2	286.00	165	43.40	
7.4	1	2	2½	342.00	176	46.30	B
7.7	4/0	1	2½	356.00	195	46.30	A
8.2	250	1	2½	421.00	255	51.40	B
9.2	0	2	2½	378.00	200	41.10	A
9.5	350	1	3	532.00	310	56.00	C
11.0	2/0	2	3	468.00	232	42.50	A
11.0	500	1	3	622.00	380	56.60	C
11.2	1	3	3	472.00	231	42.20	B
13.2	3/0	2	3	521.00	264	39.50	A
13.8	0	3	3	526.00	262	38.10	A
15.4	4/0	2	3	586.00	312	38.00	A
16.4	250	2	3½	755.00	408	46.00	B
16.5	2/0	3	3½	634.00	304	38.40	A
19.8	3/0	3	3½	713.00	346	36.00	A
23.1	4/0	3	4	848.00	410	36.70	A
24.5	250	3	4½	1085.00	535	44.30	A

Wiring in steel conduit for up to 600-volt three-phase 30 C ambient NE Code ratings.

Size 250 MCM and above — Heat and moisture resistant rubber type cable insulation with 75C rating.

Below 250 MCM — Thermoplastic cable insulation with 60 C rating.

A — Preferred B — Second Choice C — Uneconomical



A suitable unit for comparing the performance of cables is P, which is defined as (1)

$$P = LxI/dV x 1000$$

where, L = feeder length in feet

I = load current in amperes

dV = feeder voltage drop

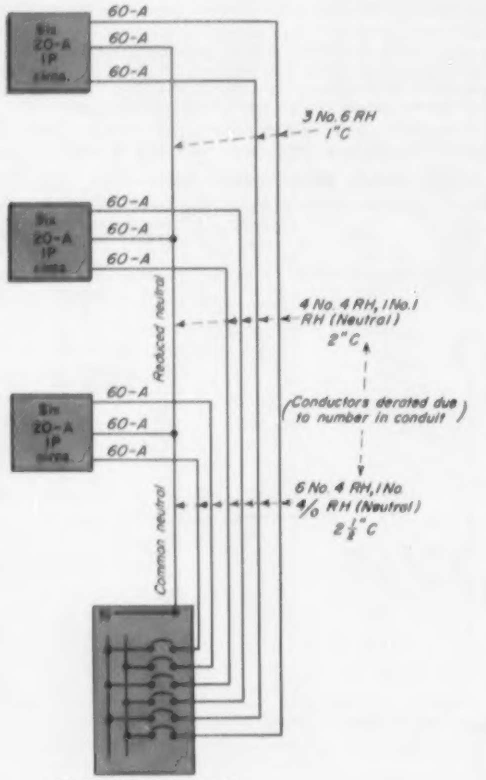
(1000 is included for brevity)

Based on the average value of load power factor, 0.8 to 0.95, it can be assumed that voltage drop in a feeder is equal to the impedance drop, so that dV in Equation (1) becomes $LIZ\sqrt{3}/1000$. Equation (1) then simplifies to $P = 1/(Z\sqrt{3})$

where, Z = ohms to neutral impedance per 1000 feet of feeder.

The higher the value of "P," the lower the voltage drop and power losses and the higher the extra capacity.

EXAMPLE OF COMMON NEUTRAL AND REDUCED NEUTRAL
(Code sections 2204 and 2410)



Feeder distribution panel 3-wire, single-phase

Note: Conductor sizes conform to reduced carrying capacities for more than three conductors in conduit.

MOTOR FEEDERS AND MAINS

For motor feeders and mains, two values of load — the maximum-demand starting current and the maximum-demand running current — must be determined separately. Although the NEC allows use of the maximum-demand running current in determining size of conductors required to carry the current safely, it is better practice to use the maximum-demand starting current in sizing conductors, since the protection of the circuit can be provided against both straight overloads and short circuits. The maximum-demand running current is used for determining circuit voltage drop. The maximum-demand starting current is used in determining the proper size of protective equipment for the circuit. Average starting currents of motors are given in Tables 26 and 27 of the NEC. Average full-load rated currents of motors are given in Tables 21, 22, 23 and 24 of the NEC. Maximum-demand starting and running currents for motor feeders and mains are determined as follows:

Starting current $= I_S + (DF \times I_T)$

Running current $= (1.25 \times I_F) + (DF \times I_T)$

where $I_S =$ starting current of largest motor

$I_T =$ sum of full-load rated currents of all motors except largest

$I_F =$ full-load current of largest motor

$DF =$ demand factor

Notes — Where a number of motors of the same size are the largest in the group, one of these motors should be taken as the largest for solution of the above. Permission for use of a demand factor must be obtained from the authority enforcing the Code.

POWER FACTOR OF FEEDERS OR MAINS

The power factor of a circuit supplying several motors is determined as follows:

1. For each motor, multiply its horsepower by its power factor at 75% of rated load.
2. Add up these products for all of the motors.
3. The sum obtained in "2" divided by the total horsepower connected to the circuit will give the approximate (but accurate enough for most calculations) power factor of the circuit.

types, with either fuse or circuit breaker protection for the feeders or subfeeders originating in them. Such panelboards are generally used as the main feeder distribution center in small and medium sized commercial and institutional buildings and in some small industrial occupancies. In many cases, this panelboard will contain the service disconnect and protection. Article 384 of the code covers panelboards and switchboards.

Motor feeders may be carried to a motor control center, to a power panelboard, to a subfeeder switchboard or panel or to individual motor branch circuits tapped from the feeder. Motor subfeeders may be carried to a motor control center, to a power panelboard or to individual motor branch circuits. A power panelboard is a fused-switch, circuit breaker or fuse panelboard from which motor branch circuits originate. It may provide simply protection for the branch circuit conductors or may also provide disconnect means for each motor load. A motor control center is a dead-front assembly of cubicles, each of which contains branch-circuit overcurrent protection, motor disconnect means, motor controller and motor running overcurrent protection. It is a type of switchboard which contains all the protective and control means for the motors supplied from it. Selection and application of power panels and motor control centers should be related to future requirements. Such units must have necessary spare capacity in their buses and must be adapted to whatever change or expansion is anticipated. Layout of power panels and motor control centers should be related to voltage drop and the lengths of feeders versus branch circuits to motors.

Laying Out Motor Feeders

Layout of motor distribution systems will depend upon the type of building, construction characteristics of the building and the number, sizes and types of motors to be served:

Miscellaneous motor loads in the majority of commercial and institutional buildings and in many industrial buildings are usually circuited from power panels to which feeders deliver power. This type of distribution is a standard method of motor circuiting, generally limited to handling a number of motors of small integral horsepower or fractional horsepower sizes, located in a relatively small area such as a fan room or pump room. The feeder to a power panel may be a riser in a multi-story commercial or institutional building, run from a basement switchboard. In a one-level industrial area, the feeder to a power panel may be run from a main or load-center switchboard or from a load-center substation in a high voltage distribution system. In commercial and industrial buildings, motor feeders may be run from a main switchboard or a load-center substation to a motor control center serving a large group of motors in a machine room or in any compact area where the motors are relatively close together and close to the control center assembly. The motor control center contains all the control, protection and disconnecting means for the motor circuits supplied.

In industrial buildings, where a large number of motors are used over a large area, distribution of power to the individual motor loads generally follows the method of tapping motor branch circuits from the feeder. As was indicated in the discussion of "Branch Circuits", tapping a feeder to motor branch circuits may be done in several ways, by providing various combinations of branch circuit overcurrent protection and motor control and disconnect means. The feeder in such an arrangement may originate from a main switchboard or from a load-center substation. In multi-story buildings, such as office buildings or institutions taps to motor branch circuits on a particular floor may be taken from a subfeeder originating in a load-center switchboard which is fed by a riser from the main switchboard in the basement. The feeder-tap method of supplying motor branch circuits is, of course, the basis for plug-in busway distribution to spread-out motor loads. In the system, the plug-in busway may be a feeder or subfeeder depending upon its origin. From a main switchboard, it would be a feeder. From a load-center switchboard, it would be a subfeeder. However, from a load-center substation, the plug-in busway would be a feeder —a secondary feeder derived from the transformation down from the primary feeder to the substation.

Load-Center Substations

Design of electrical systems for modern industrial plants varies widely with the nature of the activity. However, electrical distribution within all industrial occupancies has the same general objective —to get required power to load devices as economically and efficiently as possible. Design of a distribution system to meet this requirement in any plant or area is greatly affected by such considerations as: the importance of power continuity and the relation of power outages to production or processing operations; economy of installation and operating costs; the flexibility requirements of the particular type of industrial activity; safety and protection of personnel and equipment. Depending upon the conditions and requirements in any case, design of an industrial distribution system may incorporate such modern techniques as load-center distribution from unit substations,

TYPICAL MOTOR CIRCUIT CALCULATIONS

A feeder supplies four motors as follows:
1 — 50 hp-squirrel-cage induction motor (full-voltage starting)
1 — 30 hp-wound-rotor induction motor
2 — 10 hp-squirrel-cage induction motors (full-voltage starting)
The feeder is a 3-phase, 440-volt, 60-cycle supply.
From Table 24 of the code (see the section on BRANCH CIRCUITS), the motors have full-load current ratings as follows:
50-hp motor = 63 amps — which requires No. 3 R or No. 4 RH branch circuit conductors
30 hp motor = 39 amps — which requires No. 6 R or No. 6 RH branch circuit conductors
10-hp motor = 14 amps — which requires No. 12 R or No. 12 RH branch circuit conductors
The feeder conductors must have a carrying capacity as follows:

$$1.25 \times 63 = 79 \text{ amps} + 39 \text{ amps} + (2 \times 14 \text{ amps}) = 146 \text{ amps}$$

The feeder conductors must then be No. 3/0 R or No. 1/0 RH

OVERCURRENT PROTECTION (From Code Table 20)

1. The 50-hp motor must be protected at not more than 80 amps for running overcurrent protection and not more than 200 amps (fuse) for branch circuit protection.
2. The 30-hp motor must be protected at not more than 50 amps for running overcurrent protection and not more than 60 amps (fuse) for branch circuit protection.
3. Each 10-hp motor must be protected at not more than 20 amps (non-adjustable protective device) for running overcurrent protection and not more than 45 amps (fuse) for branch circuit protection.

FEEDER OVERCURRENT PROTECTION (Code Table 27)

1. The maximum ratings of branch circuit fuses to protect the motor branch circuits are as follows (from Table 27):

50-hp motor = 63 amps x 300% = 189 amps
30-hp motor = 39 amps x 150% = 59 amps
10-hp motor = 14 amps x 300% = 42 amps
Maximum allowable size of feeder fuses is (from sec. 4362):

$$189 + 39 + 14 + 14 = 256 \text{ amps, or } 300 \text{ amp fuses}$$

Note: The values obtained by these calculations are minimum basic sizes and ratings required for the given load. Use of circuit breaker protection would involve other calculations. And voltage drop and line losses would also have to be considered. Overall layout and choice of equipment could also affect ultimate sizings.

Voltage Drop Calculations Including Conductor Reactance

When current flows in a conductor in which the reactance due to self induction is negligible, the voltage drop is equal to the product of the current in amps and the total resistance of the conductor in ohms. But when the reactance of the conductor is not negligible, the voltage drop is equal to the product of the current in amps and the total impedance of the conductor, which is determined from the formula

$$Z = \sqrt{R^2 + X^2}$$

in which, Z = total impedance in ohms
R = total ac resistance of the conductor in ohms
X = reactance of the conductor in ohms

The voltage drop in such a conductor is

$$V = IZ$$

in which, V = voltage drop (volts)
I = current flowing in conductor (amperes)
Z = total impedance of the conductor (ohms)
(see manufacturers' bulletins and catalogs for conductor impedance values in ohms per 1000 ft)

Resistance and reactance data on wires and cables are given in literature made available by the manufacturers. Tables and graphs for quickly and easily computing voltage drop in large, heavily-loaded feeders operating at less than unity power factor and with considerable conductor reactance are also available.

NOTES:

1. Reactance in conductors carrying ac power depends upon the size of the conductor, spacing between it and other conductors carrying current, the position of the conductor with respect to conductors close to it, the frequency of the alternating current and the presence of magnetic materials close to the conductor. In an ac circuit, the reactance of the conductors may be reduced by placing the conductors close together and/or by placing them in non-magnetic raceway instead of steel conduit or raceway. In many large size or long ac circuits, the voltage drop due to impedance is often far greater than the drop due simply to resistance of the conductors.
2. Alternating current flow in conductors is subject to "skin effect" which is an apparent increase in resistance over the resistance value which would obtain for direct-current flow. This is due to a reduction in effective conductor cross section because alternating current tends to flow close to the surface (or "skin") of the conductor. Generally, this increase in resistance to ac is of little consequence in conductors smaller than 500 MCM.

high-voltage distribution to unit substations and alternative supply to each substation. The load-center substation is the key to this modern industrial distribution.

In the layout of load-center distribution, load-center unit substations are located in the approximate center of the area occupied by the load devices supplied from the substation. Of course, the exact location of a substation with respect to the equipment it supplies depends upon the number and relative sizes of the load devices and the construction characteristics of the building. The number of unit substations required in any installation will depend upon the total load to be served and the capacities of the individual unit substations. Each substation is fed by high-voltage (2400 volts to 13,800 volts) incoming power lines, transforms the power down to low voltage (under 600 volts) and supplies feeders to motors and other power loads and feeders to lighting loads, either directly—for 277-volt lighting—or indirectly through step-down transformers for 120-volt circuits.

The use of load-center substations allows efficient and economical distribution of large bulks of power throughout a plant. Distributing power at high voltages requires much lower feeder current-carrying capacities than would be required to distribute the same amount of power at low voltage. As a result, the primary feeders are relatively small in size and not subject to the severe voltage drop conditions which result from the use of long, low-voltage but high-current feeders to load concentrations. And the locations of the unit substations, in the center of each load concentration, permit the use of very short secondary feeders to loads, again minimizing voltage drop and copper loss.

Many advantages may be realized through the use of load-center distribution in industrial plants. It has been estimated that the savings in feeder copper alone may run as high as 20%. And other substantial savings are effected through elimination of heavy capacity secondary switchgear. In addition to initial economy, load-center distribution provides unusual flexibility and adaptability to expansion of facilities at a later date, offering long range economies. The installation and connection of unit subs into a system is a relatively simple and easy matter, following manufacturer's instructions and minimizing special and detailed engineering work.

Design of a load-center distribution system for any industrial plant begins with analysis and breakdown of the total load within the building. From this study, the number and sizes of load center subs will be determined. In general, the total load in the plant is broken into blocks and apportioned among a number of unit substations. Generally, the smaller the unit sub, the more expensive it is per kva. And the greater the number of unit subs, the greater the amount of primary cables. But the use of a large number of unit subs, each covering only a small area of load accumulation, reduces the lengths of secondary feeders. The use of a small number of very large subs, however, requires less primary conductors but more secondary conductors, with an increase in the cost of switchgear. From investigation of standard kva ratings of unit subs and system costs per kva, it has been found that economy usually dictates the use of unit subs rated from 500 to 1500 kva. Maximum economies, however, can be realized from the use of substations rated from 750 to 1000 kva.

A typical load-center substation contains high-voltage switchgear in an incoming section, a transformer section in which the power is stepped to low voltage and a section containing switching and protection for the outgoing secondary feeders. High-voltage switchgear may utilize circuit breakers or interrupting switches with or without power fuses. A number of oil-filled or dry type transformers are used in unit subs, offering advantages for indoor and outdoor applications. Secondary switching and protection usually consists of com-

pletely enclosed assemblies of draw-out type circuit breakers.

Layout of Substations

One of the most important considerations in the use of load-center substations is the layout or circuiting arrangement used. Typical systems are: radial, secondary selective, primary selective and network. An accompanying illustration covers the various systems with remarks on the application of each. Further information on the particular advantages of the different system circuits can be obtained from manufacturers' literature and from their application engineers.

Of the load-center distribution systems in use today, the great majority follow a simple radial pattern or secondary selective layout. The simple radial system offers a high order of reliability and service continuity and is safe, flexible, stable and easy to operate and maintain. Where more flexibility is required, use of two unit subs with a normally-open secondary tie breaker between them forms a secondary selective system. A double-ended substation, with primary supply to each end and a normally-open secondary tie within the assembly, may also be used to form a secondary selective system. In operation, each substation or each end of a double-ended sub operates as a straight radial system. If one primary feeder or transformer should fail or be taken out of service, the load normally carried on that substation or that end of a double-ended substation is automatically transferred to the still-operating substation. The secondary selective system represents a cost increase of only 5% to 15% over a simple radial system. It is widely used in manufacturing and processing plants of all types.

Primary Voltage

Selection of the primary voltage to be used with a load-center distribution depends upon the available utility lines, the total load to be supplied and the number of unit subs to be used. Consultation with the local utility is essential to selection of the best primary voltage. In general, primary distribution at 13.8-kv offers the best load-center design at lowest cost for very large industrial plants with demand load above 20,000-kva. Between 10,000-kva and 20,000-kva, plant load may be economically served by either 13.8-kv or 4160-volt primaries. For plants with demands below 10,000-kva, primary distribution at 4160 volts is generally recommended. Although 2400-volt primary distribution is applicable to load-center distribution, the use of 4160 volts instead offers economy in cost of switchgear and requires less feeder copper to handle the same kva of load. Interrupting capacities are higher for 4160-volt switchgear, thereby providing greater expansion possibilities without future requirements for limiting fault currents. The code places a limitation on the use of high-voltage within a building. Up to 15,000-volt lines may be carried through a building. When utility voltage is below 15-kv, the primary lines may be brought into the plant and carried directly to the unit substations, with no need for intermediate voltage transformation between the service entrance and the subs. If, however, the utility voltage is above 15-kv, a voltage step-down is required before power lines can enter the building.

Secondary Voltage

Secondary voltages for feeders from unit subs to light and power branch circuits are selected on the basis of the amount and types of load devices. Usually, 480-volt secondary feeders are used to handle motor loads, with minimum copper requirements. In such cases, dry-type transformers are fed by 480-volt feeders and step the voltage to single-phase 120/240 volts, or 120/208 volts, 3-phase, for lighting, plug receptacles and other miscellaneous

General Notes on Overcurrent Protection

Conductors in electric circuits must be protected against conditions of excessive current flow. Such protection must be provided in accordance with the current-carrying capacities of the conductors, except where particular settings or ratings of protective devices are required — as in the case of motor branch circuits or motor feeders.

If the allowable current-carrying capacity of a conductor does not correspond to the rating of a standard-size fuse, the next larger rating of fuse may be used — but the rating of the fuse must never exceed 150% of the allowable current-carrying capacity of the conductor.

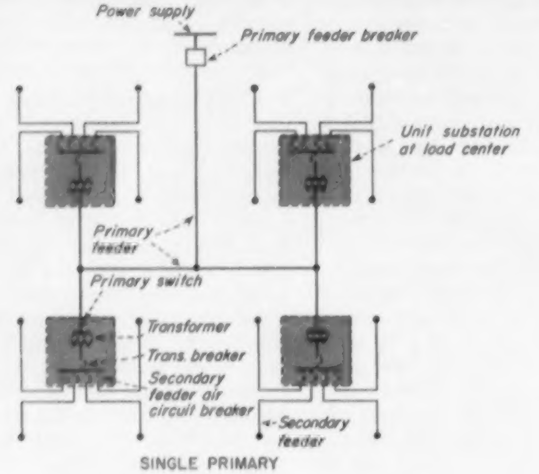
Non-adjustable-trip circuit breakers must be rated in accordance with the current-carrying capacity of the conductors they protect — except that a higher-rated circuit breaker may be used if the carrying capacity of the conductor does not correspond to a standard unit rating. In such a case, the next higher standard rating and setting may be used if it is not in excess of 150% of the current rating of the conductor. Circuit breakers in the 0 to 30 amp sizes should be of the time-delay type.

Adjustable-trip circuit breakers of the thermal-trip, magnetic time-delay trip or instantaneous-trip types must be set to operate at not more than 150% of the allowable current-carrying capacity of the conductor.

An overcurrent device must not be used in any permanently grounded conductor — except where the device simultaneously opens all conductors of the circuit, where the electrical inspector requires it or where used for motor running protection.

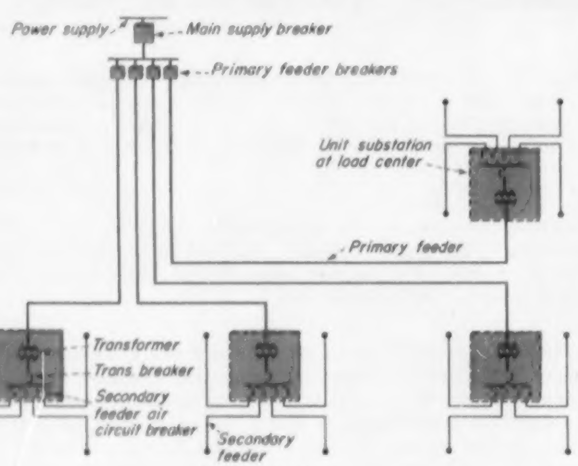
Overcurrent protection for a conductor must be located at the point where the conductor receives its supply. This means that a conductor run of a particular current-carrying capacity must be protected at the point at which it is fed by a conductor of higher current-carrying capacity. In a feeder run, then, change in conductor size (from larger to smaller) must be accompanied by protection for the smaller conductor. Exceptions to this rule are made in the case of taps and where the protection for the larger conductor meets the requirements for protection of the smaller conductor.

PRIMARY CIRCUITS FOR RADIAL LOAD-CENTER SYSTEMS



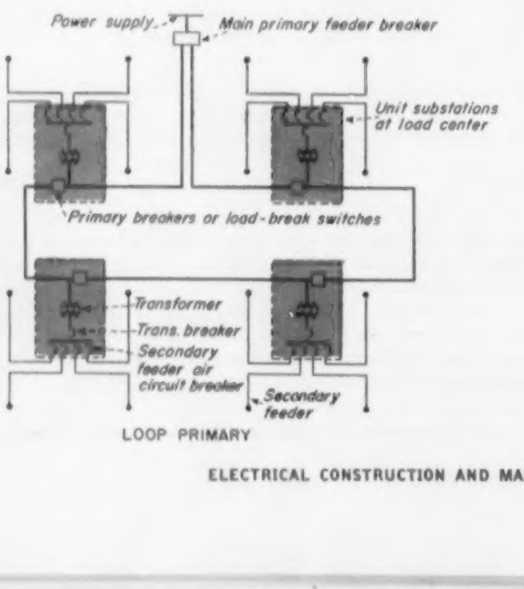
SINGLE PRIMARY

Basic radial system for high-voltage distribution with load-center substations. Used where the total system load to be served exceeds several hundred kilowatts and where the use of a single substation or secondary voltage service would result in long heavy feeders with characteristic high cost, poor voltage regulation and low efficiency. Offers advantages of high voltage distribution at lowest cost.



MULTI-PRIMARY

A variation on the basic system; has individual primary feeders to unit subs. Provides more flexible system. Reduces the effect of outages due to fault on primary feeder in basic system. Use of automatic protective devices in each primary feeder increases cost of system over basic system. Adaptability to load growth and plant changes is improved over that of the basic system.



LOOP PRIMARY

Similar to the basic system, with the primary feeder looped back on itself at the point of power supply. Increases system reliability at slight cost increase over basic system. By the use of main primary feeder breakers at the source point and automatic sectionalizing breakers at the points of tap to the load-center subs, the occurrence of primary feeder faults will not interrupt service to any loads. By opening one of the sectionalizing breakers in the loop, the system may be operated as two simple radial systems with independent primary feeder to each group of substations. The system is then a form of primary selective system.

loads. Use of 277-volt lighting for high-bay and general applications in industrial areas is derived directly from 480/277-volt secondary feeders. In very few cases, such as where considerably less than half of the total load is power, 120/208-volt 3-phase, 4-wire distribution may be derived directly from the secondaries of unit subs and carried throughout the building. Such application is rare and not recommended. Savings in copper, better regulation of voltage, lower voltage drop and line losses and greater capacity for expansion favor the use of 480-volt secondary distribution in load-center systems.

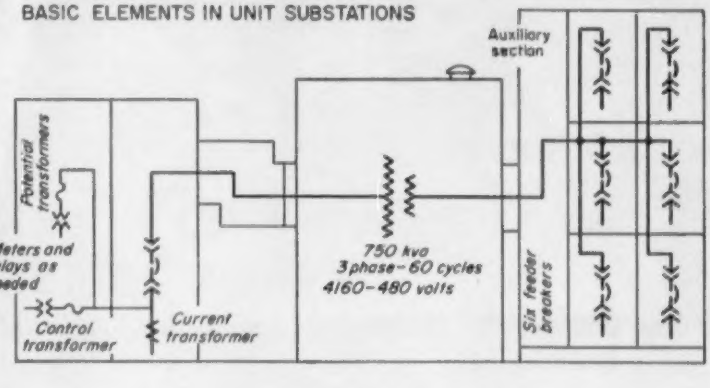
480/277-Volt Systems

Widespread acceptance and application of industrial high voltage systems has stimulated the use of higher voltages in electrical systems for commercial and institutional buildings. Up to a few years ago, 3-wire, single-phase 120/240-volt distribution systems and 3-phase, 4-wire 120/208-volt distribution systems were standards for non-industrial buildings. Today, although these lower voltage systems still find wide and efficient application, the 480Y/277-volt, 3-phase, 4-wire system is coming into common use in large commercial buildings.

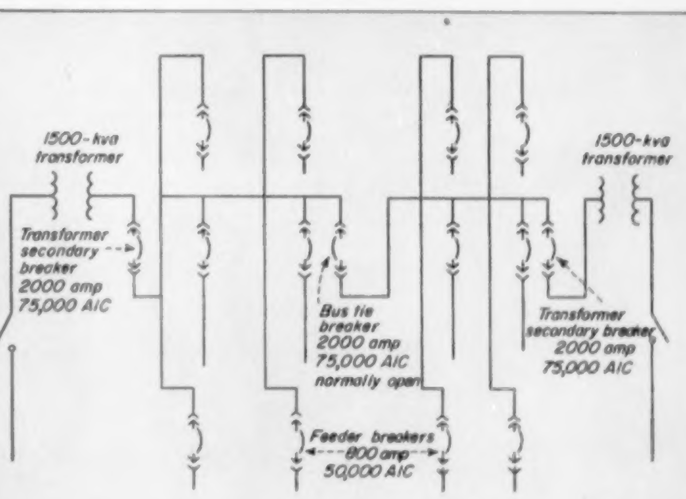
The growth of electrical loads in commercial buildings has been responsible for the development of the 480Y system which has many characteristics similar to industrial type systems. Air conditioning loads and business and other machine loads have increased the ratio of power to lighting loads, calling for the type of circuit treatments and layouts which industrial plants use to economically and efficiently serve heavy motor loads. Higher-voltage feeders to motor loads and to step-down transformers for lighting and receptacle circuits proved the ideal solution. Less copper was needed to distribute the heavy power requirements, and voltage drop and other losses were also minimized. The development of lighting equipment which would operate on 277-volt circuits contributed greatly to the success of the system. From studies made, it has been found that a 480Y system can provide savings of more than $25 per kva demand over a 120/208-volt system to handle the same load.

The 480Y system has been developed to meet the requirements of prevailing commercial building load conditions. In general, most general lighting is fluorescent and can be served by 277-volt circuits. Motors for air conditioning compressors, circulating fans, elevators and pumps make up an average load of about 4 volt-amperes per square foot. These motors can be more efficiently and economically supplied at 480 than at lower voltages, and they are less expensive than lower voltage motors of the same hp ratings. The combined power and general lighting loads average between 4 and 10 watts per square foot. Receptacle and miscellaneous loads—desk lamps, local lights, business machines, appliances, water coolers, etc.—average about ½ to 2 watts per square foot. As can be seen, about 80% of a building load may be served directly by 480-volt feeders. Provision of 120-volt circuits may be made either by using separate 120/208-volt substations or by using the previously mentioned 480- to 120-240-volt dry type transformers in-

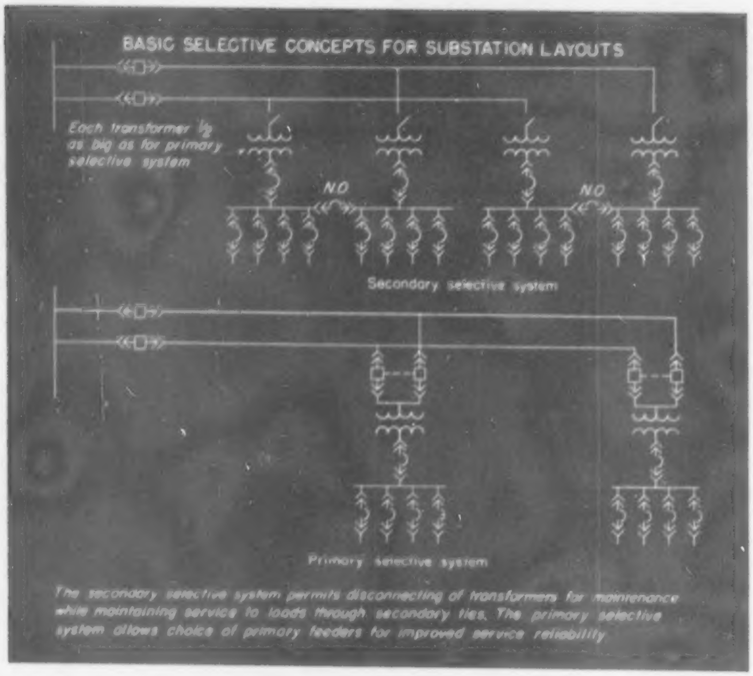
BASIC ELEMENTS IN UNIT SUBSTATIONS



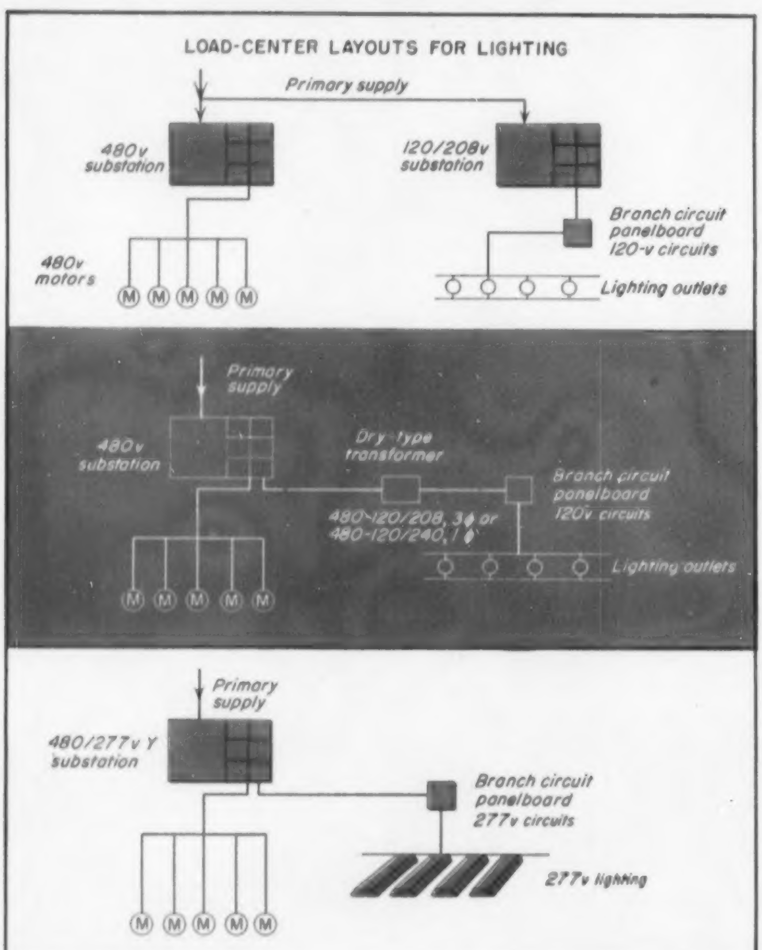
A typical load-center substation contains: switchgear, protection and metering equipment for the incoming primary line (at left); a transformer for stepping high voltage power to a utilization voltage level; and a section of disconnect and protection devices for the secondary voltage feeders which originate in the substation assembly. A double-ended substation, shown below, is really two single subs with a tie breaker between them.



Three breakers, one tie and two main, provide additional reliability accorded by double-ended substations. If one transformer is down, its load is easily transferred to the other.



The secondary selective system permits disconnecting of transformers for maintenance while maintaining service to loads through secondary ties. The primary selective system allows choice of primary feeders for improved service reliability



stalled locally at the center of each concentration of 120-volt loads. The latter method offers greater economy, even when the amount of 120-volt loading is as high as 5 watts per square foot.

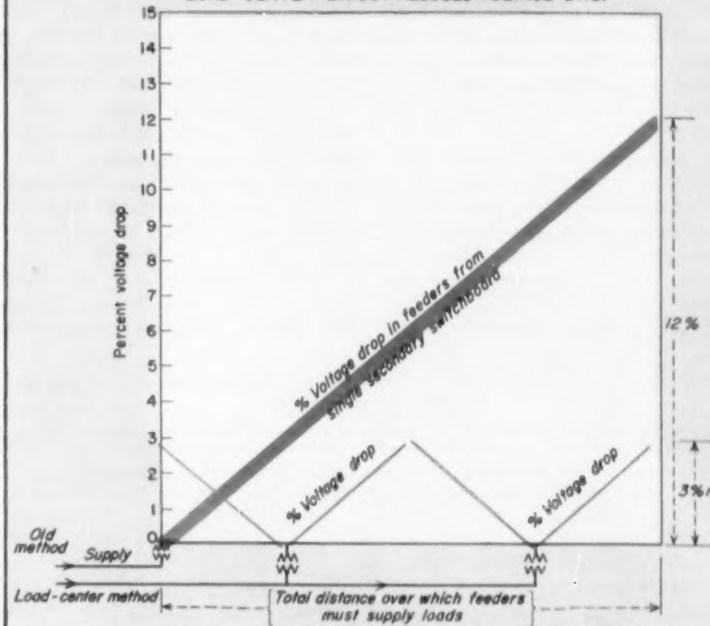
One of the important design considerations involved in 480Y/277-volt systems is that of short-circuit protection. Available equipment for such systems incorporates adequate short circuit protection for use where short-circuit duty at the main switchboard does not exceed 100,000 amps at 480 volts. Current-limiting fuses are used in switchgear, panelboards and circuits. When the possible short-circuit current is greater than 100,000 amps, interrupting capacities can be reduced to 100,000 amps by using service entrances rated not greater than 4000 amps per entrance and connecting from the network bus to the main switchboard with high-reactance busway. With motor control centers, current-limiting reactors may be used in the incoming line section to limit available short-circuit current.

Wiring Systems

Although busway and interlocked armor cable are gaining rapidly in feeder applications, conduit and cable feeders are still the most widely used in commercial, institutional and industrial buildings. The number of conductors permitted in a particular size of conduit is covered in the code, in Tables 4, 5 and 9 for conductors all of the same size and in Table 11 for a combination of conductors of different sizes. For non-lead covered conductors, four or more to a conduit, the sum of the cross-sectional areas of the individual conductors must not exceed 40% of the interior cross-sectional area of the conduit or tubing. Of course, to fill conduit to the code allowance is a minimum practice and frequently difficult or impossible from the mechanical standpoint of pulling the conductors into the conduit, due to twisting or bending of the conductors within the conduit. Bigger-than-minimum conduit should generally be used to provide some measure of spare capacity for load growth, and in many cases, the conduit to be used should be upsized considerably to allow future installation of some larger, anticipated size of conductors.

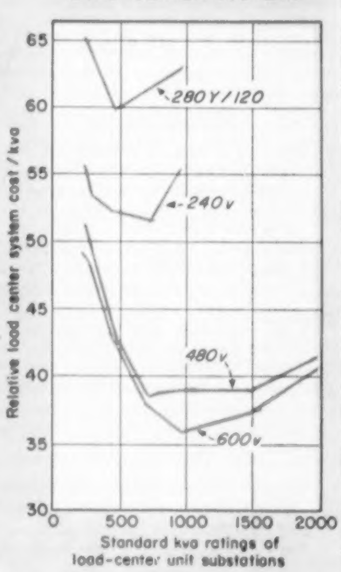
When sizing feeder conductors on the basis of the loads to be served, the voltage drop to be expected and the computed amount of spare capacity, the derating factors applicable to conductors in conduit must be applied. According to Note 4 following Tables 1 and 2, "Table 1 gives the allowable current-carrying capacity for not more than three conductors in a raceway or cable. If the number of conductors in a raceway or cable is from four to six, the allowable current-carrying capacity of each conductor shall be reduced to 80% of the values in Table 1. If the number of conductors in a raceway or cable is from seven to nine, the allowable current-carrying capacity of each conductor shall be reduced to 70% of the values in Table 1." The code makes exception for this requirement in the case of Wireways (Art. 362), Auxiliary Gutters (Art. 374) and Low-Energy Power, Low-Voltage and Signal Circuits (Art. 725). Wireways or auxiliary gutters may contain up to 30 conductors at any cross section (excluding signal circuits and control conductors used for starting duty only between a

LOAD-CENTER LAYOUT REDUCES VOLTAGE DROP



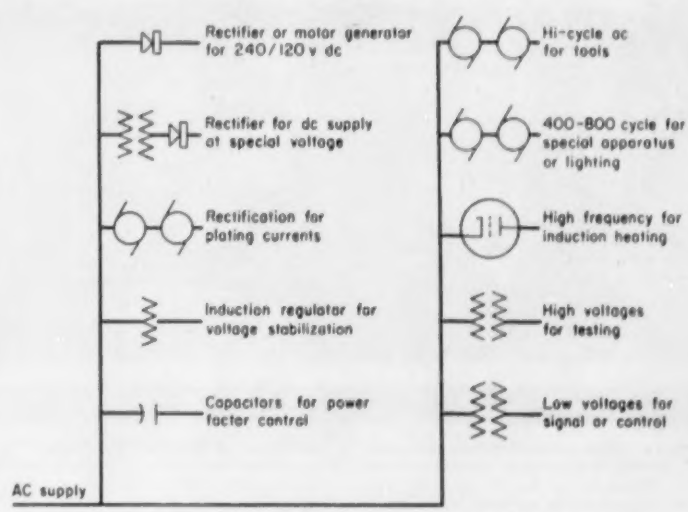
In the case of the load-center layout, shorter feeders cover the same distance over the plant as the long secondary feeders from the single switchboard, but the voltage drop is greatly reduced in the load-center system. Improved voltage regulation adds up to overall increase in operating efficiency of the system.

RELATIVE ECONOMIES OF LOAD-CENTER SYSTEMS



From this chart, it can be seen that costs of load-center distribution systems vary with the size of unit substations used in the systems and with the utilization voltage derived from the system. Unit subs between 750 kva and 1500 kva, with 480-volt secondary distribution, offer the greatest economy overall.

EQUIPMENT FOR MODIFYING ELECTRICAL CHARACTER OF DISTRIBUTION



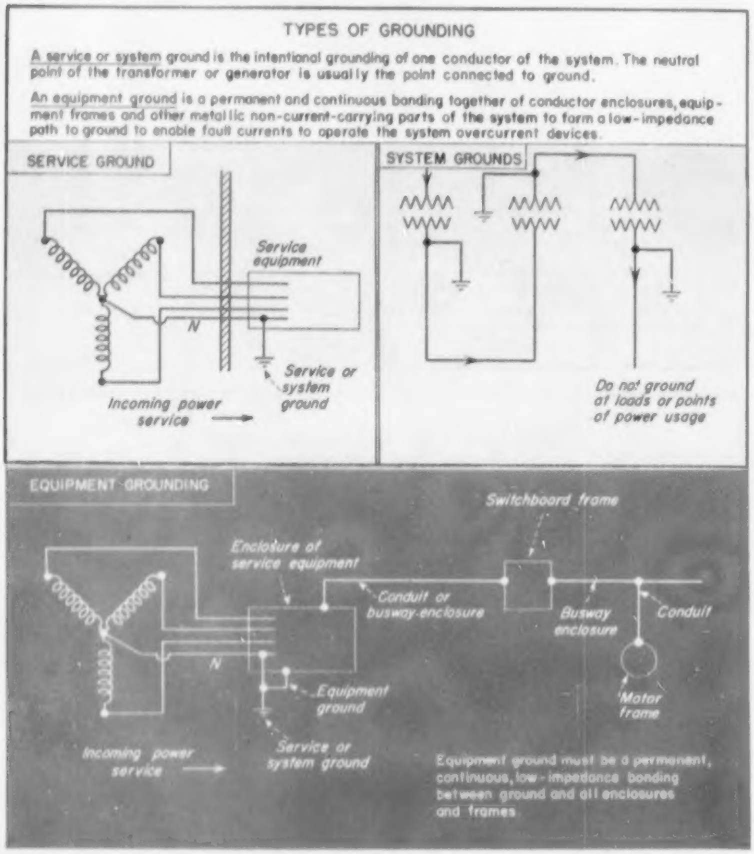
Modification or refinement of the characteristics of the distribution voltage often have to be made for such purposes as those indicated in the above diagram. In such cases, the designer must analyze the load served from the various types of equipment shown and determine the magnitude and characteristics of each load as it is reflected back into the distribution system. Manufacturers' instructions should be carefully followed, and engineering assistance of the manufacturer should be sought in extensive or complex installations.

motor and its starter). The total cross-sectional area of the group of conductors must not be greater than 20% of the interior cross-sectional area of the wireway or gutter. And derating factors for more than three conductors do not apply.

It should be noted that neutral conductors which carry only unbalanced current from phase conductors (as in the case of normally balanced 3-wire, single-phase or 4-wire, 3-phase circuits) are not counted when determining the current derating of conductors on the basis of the number in a conduit, as just described. Of course, a neutral conductor used with 2-phase legs of a 4-wire, 3-phase system to make up a 3-wire feeder is not a true neutral in the sense of carrying only current unbalance. Such a neutral carries the same current as the other two conductors under balanced load conditions and must be counted as a conductor when derating more than three conductors in conduit.

Feeder conduit may be rigid conduit or electrical metallic tubing for 2-in. or smaller size conduit. Rigid metal conduit provides excellent mechanical protection for the conductors, encloses possible faults and is a low resistance path to ground to assure quick operation of circuit protective devices in the event of fault currents. EMT offers light weight, with ease of handling, cutting and bending.

Other types of conduit and raceways have also found considerable application in modern electrical design. Cable troughs are metal trays of large mesh construction, now widely used for racking and routing feeder cables in many types of industrial buildings. Troughs provide a sturdy, flexible system for supporting feeder cables, particularly where routing of the runs is devious or where provision for change or modification in circuiting is important. The use of asbestos-cement ducts with feeder conductors is also used, offering minimum voltage drop due to conductor reactance. Still another type of conduit used in modern distribution is flexible polyethylene plastic raceway. In one application, this type of raceway was used for both primary (5-kv) and secondary underground distribution. Primary circuits consisted of single-con-



RULES FOR GROUNDING

Ground at power source or power sources only. See Service Ground and System Grounds above. Power source may be point at which utility lines come into building. If transformations are made to several voltage levels, ground each level at the transformer secondary. Do not ground at points of power utilization.

On low-voltage circuits, impedance of the equipment ground must not limit fault current below rating of protective device.

All parts of the complete system must be grounded. Ground at each major bus section if it is possible to separate each bus section.

Except on low-voltage generators equipped with special coil bracing, generator neutrals must not be grounded solidly. A grounding reactor should be used on Y-connected low-voltage generators, and a grounding resistor on high-voltage units.

Neutral grounded systems require overcurrent devices for all phases. Only two running overload relays are required for running protection of motors.

If it proves economical, a grounding transformer may be used where a system neutral is not available.

The service ground conductor should have a carrying capacity not less than 25% of the main service capacity.

Sizing Unprotected Feeder Taps

A feeder or subfeeder may be tapped by conductors of lower current-carrying capacity without providing protection for the conductors, under the following rules:

1. If the smaller conductors used for the tap
   a. have a current-carrying capacity of not less than the sum of the allowable current-carrying capacities of the conductors of the one or more circuits or loads supplied by the tap,
   b. are not over 5 ft in length and do not extend beyond the switchboard, panelboard or control devices which they supply, and
   c. are enclosed in conduit, tubing or in a metal gutter when not part of the switchboard or panelboard —

   then the tap conductors do not have to have overcurrent protective devices at the point of connection to the feeder or subfeeder.

2. If the smaller conductors used for the tap
   a. have a current-carrying capacity at least one-third that of the feeder or subfeeder conductors,
   b. are suitably protected from mechanical injury,
   c. are not over 25 ft in length, and
   d. terminate in a single circuit-breaker or set of fuses which will limit the load on the tap conductors to their allowable rating from code Table 1 or 2 —

   then the tap conductors do not have to have overcurrent protective devices at the point of connection to the feeder or subfeeder.

ductor neoprene-jacketed cables in 4-in. plastic conduits direct-buried in a trench.

Busways and Interlocked Armor Cable

One of the fastest growing applications in modern electrical design is the busway system. Although use of busway for feeders, plug-in subfeeders and branch circuit systems has been a continuing industrial system development through past years, the use of feeder and plug-in busway in large commerical and institutional buildings is only now coming into acceptance. Busway has proved a versatile, flexible and economical method of electrical distribution. Offering safety, reliability, ease of layout and efficient operation, busway systems require only basic engineering in their design. And they are capable of carrying large and small blocks of power from main switchboards to load centers to loads. Although busways have broad application potential, they are limited. The 1953 National Electrical Code rules that "busways may be used *only* for exposed work." This answers the question which was often raised as to the use of busways for concealed work.

Made up of copper or aluminum busbars mounted on insulators within a steel housing, busway is available in a number of types and sizes for use in distribution systems. Low-reactance, ventilated feeder busway provides low voltage drop characteristics due to close spacing and special construction of the busbars which minimizes reactance. This type of busway is used for all types of high capacity feeders and risers. Because of its low reactance, it has also found application in high frequency distribution system. Typical ratings on such busway range from 600 amps to 4000 amps, for single-phase (2 or 3 poles) or 3-phase (3 or 4 poles), for 120/240-volt single-phase systems, for 120/208-volt or 480/277-volt 3-phase, 4-wire systems or for 3-phase, 3-wire systems, all up to 600 volts. Feeder busways are also available in weatherproof type. Plug-in distribution busway, with easily accessible plug-in openings for tapping to loads directly or through switch and protective devices, is available in ratings from 225 amps to 1500 amps. Busways are factory-assembled and supplied

GROUNDING OF CIRCUITS

All interior alternating-current wiring systems must be grounded if they can be so grounded that the maximum voltage to ground does not exceed 150 volts. Where the maximum voltage to ground would be above 150 volts but not over 300 volts, it is recommended that ac systems be grounded. Higher voltage ac systems may be grounded, but the code does not require or recommend it.

Direct-current systems — both 2-wire and 3-wire — must also be grounded if the voltage to ground will not exceed 300 volts. A 2-wire dc system, with no more than 300 volts between conductors, must be grounded unless it is used for supplying industrial equipment in limited areas and is equipped with a ground detector. In a 3-wire dc system, the neutral conductor must be grounded.

Grounded neutral systems are generally recommended for high voltage distribution. Although ungrounded systems do not undergo a power outage with only one-phase ground faults, the time and money spent in tracing faults indicated by ground detectors and other disadvantages of ungrounded systems has consistently favored the use of grounded neutral systems. Grounded systems are more economical in operation and maintenance. In such a system, if a fault occurs, it is isolated immediately and automatically.

Grounded neutral systems have many other advantages. The elimination of multiple faults caused by undetected restriking grounds greatly increases service reliability. The lower voltage to ground which results from grounding the neutral offers greater safety for personnel and requires lower-voltage equipment ratings. And on high voltage (above 600) systems, residual relays can be used to detect ground faults before they become phase-to-phase faults which have substantial destructive ability.

CONDUCTORS FOR GROUNDING

1. Size of grounding conductor for a wiring system or for a common grounding conductor and
2. Size of grounding conductor and raceway for service equipment in ungrounded system

Size of Largest Service Conductor or Equivalent for Multiple Conductors	Size of Grounding Conductor: Copper Wire AWG No.	Conduit or Pipe Trade Size (inch)	Electrical Metalic Tubing Trade Size (inch)
2 or smaller	8	½	½
1 or 0	6	½	1
00 or 000	4	¾	1¼
Over 000 to 350,000 c.m.	2	¾	1¼
Over 350,000 c.m. to 600,000 c.m.	0	1	2
Over 600,000 c.m. to 1,100,000 c.m.	00	1	2
Over 1,100,000 c.m.	000	1	2

Size of grounding conductor and raceway for equipment grounds (Conduit, raceways, enclosures and frames)

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)	Size of Grounding Conductor: Copper Wire No.	Conduit or Pipe (inch)	Electrical Metallic Tubing (inch)
20	16*	½	½
30	14	½	½
40	12	½	½
60	10	½	½
100	8	½	½
200	6	½	1
400	4	¾	1¼
600	2	¾	1¼
800	0	1	2
1000	00	1	2
1200	000	1	2

*Permissible only when part of an approved cable assembly.

STEP-BY-STEP CIRCUIT DESIGN

The diagram at right shows one small part of the distribution system for a large convention hall. Air conditioning and other power loads made up the major part of the total load, dictating the use of 480-volt distribution. A 3-phase, 3-wire system was used with local step-down for lighting loads. A study of the diagram affords a clear understanding of the details and procedure for distribution design.

STEP ONE

Starting at the load, branch circuit design (as described in the section on Branch Circuits) involved provision of circuits to handle a load of 500-watt incandescent units recessed in the ceiling of the convention hall as part of the general lighting treatment for the main arena. By using 50% loading of circuits, four 30-amp circuits would do the trick. Actually, this does not represent extremely conservative loading for these circuits because the load is fully operating over long periods of time and the code requires that circuit loading be limited to 80% of the circuit rating under such conditions. And because the circuits are long to cover part of the very broad ceiling area, the matter of voltage drop absorbs some of the extra circuit capacity. From study of the possible requirements, it was decided to provide two spare 30-amp circuits for future needs. A 6-circuit panelboard was then selected for use in the space above the ceiling, with a contactor to allow control of the panel (and the lighting supplied from it) from the control room overlooking the main interior.

STEP TWO

Sizing of the feeder to the panel and the contactor ahead of the mains was the next step. First, 1800 watts — 50% of capacity for each 120-volt circuit — was assumed for each of the six circuits, both active and spare. This is recommended procedure in the discussion of feeder loads in this section of the report. For the six circuits, the total load to be served by the feeder is then 6 times 1800 or 10,800 watts. Note that a demand factor of 100% must be used here because the entire load will be operating at one time (and of course, the table of code demand factors for feeders in section 2203 requires 100% demand for "Auditoriums and Armories"). At 240 volts, then, the feeder to the panel must have a carrying capacity at least equal to 10,800 watts divided by 240, which is 45 amps. Another way in which this could have been arrived at involves the amp ratings of the circuit loads. If each circuit is loaded to 50% of rating, that is 15 amps per 30-amp circuit. Dividing the number of circuits between the two hot legs and the ground in the panel, puts three 15-amp loads on each phase leg, which comes out 45 amps per phase leg. Then, from section 2203-g in the code, the neutral must be capable of carrying 45 amps because that would be the load imposed upon the neutral if the three circuits connected to one phase were operating and the three circuits connected to the other phase were not operating — the condition of maximum unbalance. From code Table 1, the feeder to the panel could be three No. 8 Type RH conductors with 45 amp carrying capacity or three No. 6 Type R conductors with 55 amp carrying capacity. Because of the relation of the load current to the rating of No. 8's, it was decided to use No. 6's with the extra capacity to reduce voltage drop. From code Table 4, three No. 6's need a 1-in. conduit.

STEP THREE

Because the distribution system is 480-volt, 3-phase, 3-wire, transformation to the utilization voltage level for lighting must be made. Obviously, the best place to transform voltage level is as close to the panelboard as possible, so the long run from the distribution panelboard can be made at the higher voltage (but lower current value) with consequent economy in amount of copper used. In this case, the dry type step-down transformer is mounted adjacent to the lighting panelboard. As was determined before, the load to be served is 10,800 watts (including spare capacity). Because the load is incandescent lighting, with unity power factor, the value of 10,800 watts is also 10,800 volt-amps. All factors considered, a 10-kva single-phase transformer is the best size to use in this case. As shown, a transformer with a center-tapped secondary was chosen to provide a neutral.

STEP FOUR

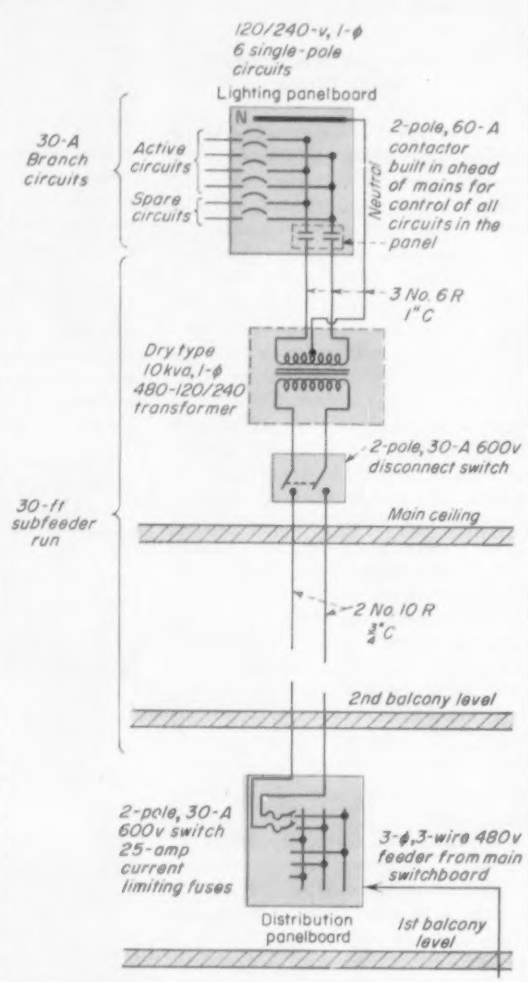
Sizing of the feeder run to the transformer (actually the run is a subfeeder, as was the run from the transformer to the lighting panelboard), is based on the full-load current drawn by the transformer, to allow eventual use of the full capacity of the transformer. The full-load current of the transformer primary is equal to 10,000 volt-amps (10 kva) divided by the primary voltage — 480 volts, which comes out to be 21 amps. The conductors to the transformer must be capable of carrying this current. No. 10 Type R conductors were therefore selected. To afford disconnect of the transformer from the subfeeder for maintenance of the transformer or the lighting panel, a 30 amp, 600-volt safety switch was placed in the subfeeder at the transformer location. The two No. 10's are carried in a ¾-in. conduit, which represents another saving over the size of conduit which would have had to be used to carry No. 6's if transformation had been made at the location of the distribution panel.

STEP FIVE

At the distribution panelboard, the No. 10 subfeeder conductors are protected by 25-amp current-limiting fuses and provided with a 2-pole, 30-amp, 600-volt disconnecting switch in the fused-switch panelboard. The 25-amp fuses afford protection to the No. 10 conductors (which can safely carry up to 30 amps) and also protect the transformer in accordance with section 4512.

NOTE. In the course of the above design, such factors as voltage drop, copper loss, relation of this part of the load to other parts of the system serving the same type of load — general lighting, interrupting ratings of protective devices and general economy requirements versus spare capacity were necessarily taken into consideration. Extension of this design approach to 3-phase circuits is a simple matter of properly using the 1.732 factor and accounting for 3-phase characteristics.

STEP-BY-STEP CIRCUIT DESIGN



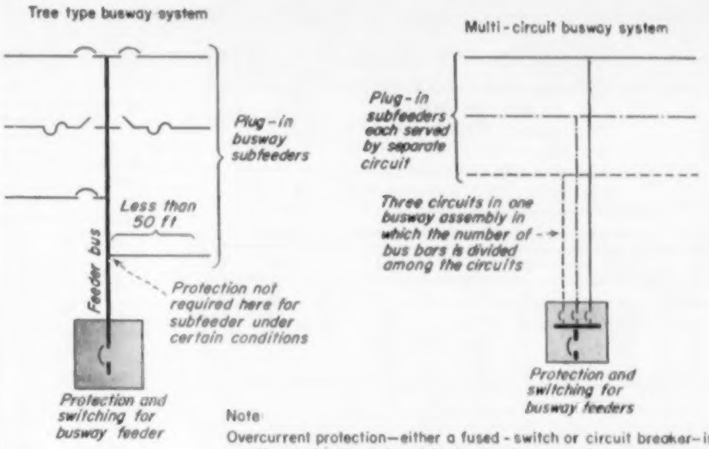
in standard 10-ft sections. They are available with copper or aluminum conductors.

Interlocked armor cable has been in use in electrical work for many years but is only now finding wide application. Interlocked armor cable is available for use at 600 volts, 5000 volts and 15000 volts. The high-voltage types of IA cable are relatively new and are used for primary feeders in load-center distribution systems. The 600-volt class of IA cable is rapidly gaining in popularity for secondary feeder applications in both commercial and industrial electrical systems.

Interlocked armor cable for secondary feeders is a completely flexible and protected cable assembly, available in sizes from No. 6 to 750 MCM, with three or four conductors. IA cable consists of a galvanized steel, interlocked and spiralled armor wrap around the insulated assembly of individually-insulated conductors. The conductors are stranded and may be copper or aluminum. The armor may also be of aluminum or bronze, to lower cable reactance and lower voltage drop. Use of IA cable is covered in the code in Article 334. Type ACV interlocked armor cable has varnish cambric insulation.

In many modern commercial and industrial electrical systems, design of the distribution system might involve choice between busway and interlocked armor cable. In such cases, only careful study of relative costs of materials and installation, analysis of requirements for future expansion and relation of all of these factors to the type of building and construction will reveal the best choice or combination of applications. Such study should also include consideration of the use of conductors in conduit and other raceway systems. There are, however, some general criteria for choosing between IA cable and busway. Where the routing is devious and there are many obstructions, IA cable often can be used to advantage. For straight runs, particularly long runs of high current capacity, busway is usually better. Above 1000 amps capacity, busway for a feeder generally costs less. Below 500 amps, a feeder may more economically be interlocked armor cable. However, where the advantages of busway are required, as for industrial plant flexibility, cost is not as important as achieving the design objectives.

LAYOUTS OF BUSWAY DISTRIBUTION



Note:
Overcurrent protection—either a fused-switch or circuit breaker—is usually required in each subfeeder tapping power from a busway feeder. This is necessary to protect the lower current-carrying capacity of the subfeeder and should be placed at the point at which the subfeeder connects into the feeder. However, the code provides that "Overcurrent protection may be omitted at points where busways are reduced in size, provided that the smaller busway does not extend more than 50 ft and has a current rating at least equal to one-third the rating or setting of the overcurrent device next back on the line..."

PROTECTION FOR TRANSFORMERS

The code requires overcurrent protection for each transformer or bank of transformers operating as a unit. Protection shall be provided as follows:

1. An overcurrent protective device — rated or set at not more than 250% of the rated primary current — must be placed in the primary connection of each transformer. Such protection, however, is not required if the overcurrent device protecting the primary circuit is rated or set at not more than 250% of the rated primary current.

2. A transformer is not required to have an individual overcurrent device in the primary connection if it has an overcurrent device — rated or set at not more than 250% of the rated secondary current — in the secondary connection, or if it is equipped with an integral thermal overload protector. In such a case, the primary feeder overcurrent device must have a rating or setting at not more than six times the rated current of the transformer for transformers having not more than 6% impedance, and not more than four times the rated current of the transformer for transformers having more than six but not more than 10% impedance.

In completely packaged, metal-clad unit substations, the transformer protection is provided as an integral part of the assembly. The switchgear and all other elements are matched to each other in accordance with the kva rating of the substation.

Dry-type and other distribution transformers must be provided with proper overcurrent protection as part of the electrical design work. The provisions of Article 450 of the code and manufacturers instructions and engineering literature should be consulted and carefully followed.

Individual dry-type transformers of the general-purpose type — used for local mounting to serve 120-volt lighting and receptacle loads in 480-volt distribution systems — are generally protected on the primary side by either a remotely-operated fuse-switch combination or a circuit breaker. The secondary side feeds directly into the branch circuit panelboard. Such transformers are generally mounted close to the center of the load they serve, require a minimum of maintenance, keep distribution losses to a minimum, eliminate the need for separate low-voltage power circuits and improve voltage regulation. They are available in ratings from 1 kva to about 500 kva.

CODE TABLES ON CONDUCTORS IN CONDUIT OR TUBING

Table 4 — Number of Conductors in Conduit or Tubing

Rubber Covered, Types RF-2, RFH-2, R, RH, RW, RH-RW, RU, RUH, and RUW

Thermoplastic, Types TF, T and TW

One to Nine Conductors

For more than nine conductors see Table 9.

(See sections 3013, 3466 and 3486)

Size AWG MCM	Number of Conductors in One Conduit or Tubing								
	1	2	3	4	5	6	7	8	9
18	½	½	½	½	½	½	½	¾	¾
16	½	½	½	½	½	½	¾	¾	¾
14	½	½	½	½	¾	¾	1	1	1
12	½	½	½	¾	¾	1	1	1	1¼
10	½	¾	¾	¾	1	1	1	1¼	1¼
8	½	¾	¾	1	1¼	1¼	1¼	1½	1½
6	½	1	1	1¼	1½	1½	2	2	2
4	½	1¼	*1¼	1½	1½	2	2	2	2½
3	¾	1¼	1¼	1½	2	2	2	2½	2½
2	¾	1¼	1¼	2	2	2	2½	2½	2½
1	¾	1½	1½	2	2½	2½	2½	3	3
0	1	1½	2	2	2½	2½	3	3	3
00	1	2	2	2½	2½	3	3	3	3½
000	1	2	2	2½	3	3	3	3½	3½
0000	1¼	2	2½	3	3	3	3½	3½	4
250	1¼	2½	2½	3	3	3½	4	4	5
300	1¼	2½	2½	3	3½	4	4	5	5
350	1¼	3	3	3½	3½	4	5	5	5
400	1½	3	3	3½	4	4	5	5	5
500	1½	3	3	3½	4	5	5	5	6
600	2	3½	3½	4	5	5	6	6	6
700	2	3½	3½	5	5	5	6	6	...
750	2	3½	3½	5	5	6	6	6	...
800	2	3½	4	5	5	6	6	...	...
900	2	4	4	5	6	6	6	...	...
1000	2	4	4	5	6	6	...	...	...
1250	2½	5	5	6	6	...	...	...	...
1500	3	5	5	6	...	...	...	...	...
1750	3	5	6	6	...	...	...	...	...
2000	3	6	6	...	...	...	...	...	...

*Where a service run of conduit or electrical metallic tubing does not exceed 50 feet in length and does not contain more than the equivalent of two quarter bends from end to end two No. 4 insulated and one No. 4 bare conductors may be installed in 1-inch conduit or tubing.

Table 9 — Number of Conductors in Conduit or Tubing

More Than Nine Conductors

Rubber-Covered Types RF-2, RFH-2, R, RH, RW, RH-RW, RU, RUH, and RUW

Thermoplastic Types TF, T, and TW

*When Specially Permitted by This Code

(See section 3012)

Size AWG	Maximum Number of Conductors in Conduit or Tubing						
	¾ Inch	1 Inch	1¼ Inch	1½ Inch	2 Inch	2½ Inch	3 Inch
18	12	20	35	49	80	115	176
16	10	17	30	41	68	97	150
14	..	10	18	25	40	59	90
12	..	..	15	21	35	50	77
10	..	..	13	17	29	41	64
8	..	..	..	10	17	25	38
6	..	..	..	..	..	15	23

*More than nine conductors are permitted in a single conduit for conductors between a motor and its controller; stage pocket and border circuits, section 5212; sign flashers, section 6021d; elevator control conductors, sections 6212 and 6213; X-ray control conductors, section 6607.

Table 5 — Number of Conductors in Conduit or Tubing

Lead-Covered Types RL and RHL — 600 V.

Size AWG MCM	Number of Conductors in One Conduit or Tubing											
	Single Conductor Cable				2-Conductor Cable				3-Conductor Cable			
	1	2	3	4	1	2	3	4	1	2	3	4
14	½	¾	¾	1	¾	1	1	1¼	¾	1¼	1½	1½
12	½	¾	¾	1	¾	1	1¼	1¼	1	1¼	1½	2
10	½	¾	1	1	¾	1¼	1¼	1½	1	1½	2	2
8	½	1	1¼	1½	1	1¼	1½	2	1	2	2	2½
6	¾	1¼	1½	1½	1¼	1½	2	2½	1¼	2½	3	3
4	¾	1¼	1½	1½	1¼	2	2½	2½	1½	3	3	3½
3	¾	1¼	1½	2	1¼	2	2½	3	1½	3	3	3½
2	1	1¼	1½	2	1¼	2	2½	3	1½	3	3½	4
1	1	1½	2	2	1½	2½	3	3½	2	3½	4	5
0	1	2	2	2½	2	2½	3	3½	2	4	5	5
00	1	2	2	2½	2	3	3½	4	2½	4	5	5
000	1¼	2	2½	2½	2	3	3½	4	2½	5	5	6
0000	1¼	2½	2½	3	2½	3	3½	5	3	5	6	6
250	1¼	2½	3	3	...	...	...	...	3	6	6	...
300	1½	3	3	3½	...	...	...	...	3½	6	6	...
350	1½	3	3	3½	...	...	...	...	3½	6	6	...
400	1½	3	3	3½	...	...	...	...	3½	6	6	...
500	1½	3	3½	4	...	...	...	...	4	6	...	...
600	2	3½	4	5	...	...	...	...	...	...	...	...
700	2	4	4	5	...	...	...	...	...	...	...	...
750	2	4	4	5	...	...	...	...	...	...	...	...
800	2	4	5	5	...	...	...	...	...	...	...	...
900	2½	4	5	5	...	...	...	...	...	...	...	...
1000	2½	5	5	6	...	...	...	...	...	...	...	...
1250	3	5	5	6	...	...	...	...	...	...	...	...
1500	3	5	6	6	...	...	...	...	...	...	...	...
1750	3	6	6	...	...	...	...	...	...	...	...	...
2000	3½	6	6	...	...	...	...	...	...	...	...	...

The above sizes apply to straight runs or with nominal offsets equivalent to not more than two quarter-bends.

See section 3470 for bends in conduit.

Table 11 — Combination of Conductors

(See sections 3466 and 3486)

For groups or combinations of conductors not included in the Tables 4 to 9, it is recommended that the conduit or tubing be of such size that the sum of the cross-sectional areas of the individual conductors will not be more than the percentage of the interior cross-sectional area of the conduit or tubing shown in the following table:

Per Cent Area of Conduit or Tubing

	Number of Conductors				
	1	2	3	4	Over 4
Conductors (not lead covered)....	53	31	43	40	40
Lead-covered conductors	55	30	40	38	35
For rewiring existing raceways for increased load where it is impracticable to increase the size of the raceway due to structural conditions	60	40	50	50	50

Note: Tables 4 to 11 apply only to complete conduit systems, and do not apply to short sections of conduit used for the protection of exposed wiring from mechanical injury.

CODE TABLES OF DIMENSIONS AND AREAS TO USE IN SIZING CONDUIT FOR COMBINATIONS OF CONDUCTORS

Table 12 — Dimensions and Per Cent Area of Conduit and of Tubing.

Areas of Conduit or Tubing for the Combinations of Wires Permitted in Table 11.

Trade Size	Internal Diameter Inches	Area — Square Inches									
			Not Lead Covered				Lead Covered				
		Total 100%	1 Cond. 53%	2 Cond. 31%	3 Cond. 43%	4 Cond. and Over 40%	1 Cond. 55%	2 Cond. 30%	3 Cond. 40%	4 Cond. 38%	Over 4 Cond. 35%
½	.622	.30	.16	.09	.13	.12	.17	.09	.12	.11	.11
¾	.824	.53	.28	.16	.23	.21	.29	.16	.21	.20	.19
1	1.049	.86	.46	.27	.37	.34	.47	.26	.34	.33	.30
1¼	1.380	1.50	.80	.47	.65	.60	.83	.45	.60	.57	.53
1½	1.610	2.04	1.08	.63	.88	.82	1.12	.61	.82	.78	.71
2	2.067	3.36	1.78	1.04	1.44	1.34	1.85	1.01	1.34	1.28	1.18
2½	2.469	4.79	2.54	1.48	2.06	1.92	2.63	1.44	1.92	1.82	1.68
3	3.068	7.38	3.91	2.29	3.17	2.95	4.06	2.21	2.95	2.80	2.58
3½	3.548	9.90	5.25	3.07	4.26	3.96	5.44	2.97	3.96	3.76	3.47
4	4.026	12.72	6.74	3.94	5.47	5.09	7.00	3.82	5.09	4.83	4.45
5	5.047	20.00	10.60	6.20	8.60	8.00	11.00	6.00	8.00	7.60	7.00
6	6.065	28.89	15.31	8.96	12.42	11.56	15.89	8.67	11.56	10.98	10.11

Table 13 — Dimensions of Rubber-Covered and Thermoplastic-Covered Conductors

Size AWG MCM	Types RF-2, RFH-2, R, RH, RH-RW, RW		Types TF, T, TW, RU**, RUH**, RUW	
	Approx. Diam. Inches	Approx. Area Sq. Ins.	Approx. Diam. Inches	Approx. Area Sq. Ins.
18	.146	.0167	.106	.0088
16	.158	.0196	.118	.0109
14	2/64 in. .171	.0230	.131	.0135
14	3/64 in. .204*	.0327*		
12	2/64 in. .188	.0278	.148	.0172
12	3/64 in. .221*	.0384*		
10	.242	.0460	.168	.0224
8	.311	.0760	.228	.0408
6	.397	.1238	.323	.0819
4	.452	.1605	.372	.1087
3	.481	.1817	.401	.1263
2	.513	.2067	.433	.1473
1	.588	.2715	.508	.2027
0	.629	.3107	.549	.2367
00	.675	.3578	.595	.2781
000	.727	.4151	.647	.3288
0000	.785	.4840	.705	.3904
250	.868	.5917	.788	.4877
300	.933	.6837	.843	.5581
350	.985	.7620	.895	.6291
400	1.032	.8365	.942	.6969
500	1.119	.9834	1.029	.8316
600	1.233	1.1940	1.143	1.0261
700	1.304	1.3355	1.214	1.1575
750	1.339	1.4082	1.249	1.2252
800	1.372	1.4784	1.282	1.2908
900	1.435	1.6173	1.345	1.4208
1000	1.494	1.7531	1.404	1.5482
1250	1.676	2.2062	1.577	1.9532
1500	1.801	2.5475	1.702	2.2748
1750	1.916	2.8895	1.817	2.5930
2000	2.021	3.2079	1.922	2.9013

*The dimensions of Type RW wire. Also, these dimensions to be used for new work in computing size of conduit or tubing for combinations of wires not shown in Table 4.

**No. 14 to No. 2.

No. 18 to No. 8, solid; No. 6 and larger, stranded.

The dimensions of rubber-covered conductors in column 3 of Table 13 are to be used in computing the size of conduit or tubing for new work for combinations not shown in Table 4. The dimensions in the last column of Table 13 may

Table 16 — Dimensions of Lead-Covered Conductors

Types RL, RHL, and RUL

Size AWG-MCM	Single Conductor		Two Conductor		Three Conductor	
	Diam. Inches	Area Sq. Ins.	Diam. Inches	Area Sq. Ins.	Diam. Inches	Area Sq. Ins.
14	.28	.062	.28 x .47	.115	.59	.273
12	.29	.066	.31 x .54	.146	.62	.301
10	.35	.096	.35 x .59	.180	.68	.363
8	.41	.132	.41 x .71	.255	.82	.528
6	.49	.188	.49 x .86	.369	.97	.738
4	.55	.237	.54 x .96	.457	1.08	.916
2	.60	.283	.61 x 1.08	.578	1.21	1.146
1	.67	.352	.70 x 1.23	.756	1.38	1.49
0	.71	.396	.74 x 1.32	.859	1.47	1.70
00	.76	.454	.79 x 1.41	.980	1.57	1.94
000	.81	.515	.84 x 1.52	1.123	1.69	2.24
0000	.87	.593	.90 x 1.64	1.302	1.85	2.68
250	.98	.754	....	....	2.02	3.20
300	1.04	.85	....	....	2.15	3.62
350	1.10	.95	....	....	2.26	4.02
400	1.14	1.02	....	....	2.40	4.52
500	1.23	1.18	....	....	2.59	5.28

Note—No. 14 to No. 8, solid conductors; No. 6 and larger, stranded conductors. Data for 2/64-inch insulation not yet compiled.

Varnished-Cambric Insulated Conductors
Type V

The insulation thickness for varnished-cambric conductors, Type V, is the same as for rubber-covered conductors, Type R, except for Nos. 14 and 12 which have 3/64-inch insulation for varnished-cambric, and 2/64-inch insulation for rubber-covered conductors and for No. 8 which has 3/64-inch insulation for varnished-cambric, and 4/64-inch insulation for rubber-covered conductors. See table in section 93101. Tables 4 and 5 may, therefore, be used for the number of varnished-cambric insulated conductors in a conduit or tubing.

Note Tables give the nominal size of conductors and conduit or tubing recommended for use in computing size of conduit or tubing for various combinations of conductors. The dimensions represent average conditions only, and while variations will be found in dimensions of conductors and conduits of different manufacture, these variations will not affect the computation.

Service

Detailed design of the one or more service entrances required to supply the electrical system in a building is the final major phase of electrical system design. Of course, during preliminary planning for the building, some decision had to be made on the characteristics of the supply or supplies which would best carry the total electrical load. From study and consultation with the local utility and/or from a knowledge of the available utility services and their capacities, the complete system was laid out to tie into the utility lines. But few details other than voltage and phase characteristics were worked out for the service arrangement. This section covers various important design considerations which are involved in laying out a service entrance, both for low-voltage systems and high-voltage systems.

For any building, the service consists of the conductors and equipment used to deliver electric energy from the utility supply lines to the interior distribution system. Service may be made to a building either overhead or underground, from a utility pole line or from an underground transformer vault. Service layout, therefore, includes electrical and mechanical factors. Conductors must be provided to connect to the utility source; suitable enclosure and mechanical protection for the incoming conductors must be considered; disconnecting means and overload and short-circuit protection are necessary; and metering and grounding must be accounted for. Step-by-step, design of the service arrangement must cover these factors in their relation to such particular conditions as the type and size of building, requirements of the National Electrical Code and local codes and the regulations and recommendations of the utility supplying the power.

Article 230 of the code covers requirements for services. Typical provisions referring to design limitation are as follows:

Although the code states that "a building shall be supplied through only one set of service conductors", there are exceptions made. If more than one service drop is made to a building, more than one set of service conductors may be used to supply the building. In the case of apartment houses, shopping centers and other multiple-occupancy buildings, two or more sets of service entrance conductors may be tapped from a single set of service drop conductors or two or more sub-sets of service entrance conductors may be tapped from a single set of main service entrance conductors. Cases of separate light and power services to a single building and separate services to water heaters for purposes of different rate schedules are exceptions to the general rule of single service.

Only one service drop may be used to supply a building from a single transformer or from a single secondary utility distribution system. Exceptions to this rule are made under several conditions. If a separate service is necessary for fire pumps or for emergency lighting, or if the size and layout of the building and its load cannot be handled by a single service, or if the building has multiple-occupancy without space for service equipment accessible to all occupants, or if an additional service of different voltage or other characteristics is needed for special classes of use, more than one service drop may be used.

Particular installation and construction requirements for overhead and underground services are covered in detail in the code. This includes wiring methods, construction of equipment and required mechanical protection for conductors.

Sizing Service Conductors

Sizing of service entrance conductors involves the same type of step-by-step procedure as used to size feeders. In general, the service entrance conductors must have a minimum current-carrying capacity sufficient to handle the total lighting and power load served. Where the code gives demand factors to use or allows the use of acceptable demand factors based on sound engineering determination of less than 100% demand requirements, the lighting and power loads may be modified in this calculation. Section 2203 of the code gives demand factors for general lighting and receptacle loads (the table listing these factors is given in the DISTRIBUTION section of this report). Section 4316 of the code allows use of demand factors for motor loads, provided the factors are approved by the code-enforcing authority. Typical power-load demand factors are given in an accompanying box in this section.

The first step in sizing the service entrance conductors is determination of the total lighting load to be served. This figure is the sum of all of the individual lighting branch circuit loads, which were determined as part of the feeder-sizing procedure. This total

Types of Service Entrance Conductors

LOW-VOLTAGE SYSTEMS

Enclosed busways — standard low-impedance (feeder) types and high-reactance types which limit available short-circuit duty for protective devices supplied from secondary networks.
Specially-designed bus bar structures.
Conductors in conduit or ducts.
Service entrance cable assemblies.
Interlocked armor cable (600 volts).
Underground direct-burial cables.
Open conductors on insulators.

HIGH-VOLTAGE SYSTEMS

Power cables in conduit or ducts.
Underground direct-burial power cables.
Cables on troughs, racks or insulators.
Interlocked armor cable (over 600 volts).

load in watts must not be smaller than the product of the total square feet of floor area in the building and the value of watts-per-square-foot given for the particular type of occupancy in the code table in section 2203. This, however, would be the barest minimum load figure for lighting. Unless it is absolutely certain that the load will not increase in the future (and when can the designer ever be sure of that), the Standard Loads for Lighting given in a table in the section on DISTRIBUTION should be used in determining lighting load on a watts-per-square-foot basis. If the total sum of actual connected loads on lighting branch circuits can be determined, a more accurate sizing of the service conductors will result. But this figure must at least be equal to the minimum watts-per-square-foot times the total floor area.

The second step in the procedure is adjustment of the total lighting load by use of demand factors. From the table in section 2203, it can be seen that in the great majority of occupancies a demand factor of 100% is used for the total wattage. This follows from the reasonable probability that in such occupancies the entire lighting load might be in operation simultaneously. There are exceptions, however. In the case of dwelling occupancies—single residences and apartment houses, hospitals, hotels, office buildings and warehouses, demand factors may be applied to various amounts of connected lighting load on the branch circuits. In those types of buildings, simultaneous operation of even a large part of the lighting load is unlikely. The service entrance conductors do not have to be able to provide power for the entire load at once. The general use of a 100% demand factor for lighting, is however, highly recommended. Even where demand factors may be applied, the designer should relate this allowance to probable conditions of utilization and raise the minimum demand factors when he thinks it necessary. In any event, the final total lighting load should be arrived at in these first two steps.

The next load, to be added to the total lighting load, is the small appliance load to be served by convenience receptacles. In apartment houses with provisions for cooking by tenants, at least 2000 watts for

Service Disconnecting Means

Service entrance conductors must be equipped with a readily accessible means of disconnecting the conductors from the source of supply. The following are the code qualifications of this general requirement:

1. The disconnect must be manually operable. It may consist of not more than six switches or six circuit breakers, in a common enclosure or individual enclosures, located either inside or outside the building wall as close as possible to the point at which the conductors enter the building. Single-pole switches or circuit breakers equipped with handle-ties may be used in groups as single disconnects for multi-wire circuits. Multi-pole switches and circuit breakers may also be used as single disconnects. The requirements of the code are satisfied if all of the service entrance conductors can be disconnected with no more than six operations of the hand—regardless of whether each hand motion operates a single-pole unit, a multi-pole unit or a group of single-pole units controlled by a single hand motion.

2. Each occupant in a multiple-occupancy building must have access to his disconnecting means. Section 2351-b covers this matter.

3. If the disconnecting means does not interrupt the grounded conductor as well as the ungrounded conductors, provision must be included in the service cabinet or switchboard for disconnecting the grounded conductor from the interior wiring.

4. For a group of buildings under single management, disconnect means must be provided for each building.

5. If an emergency power supply is provided to feed the conductors controlled by the service disconnecting means, the disconnector must be of such design that the regular supply is disconnected before the emergency supply is connected—unless special provisions are made for parallel operation and suitable control.

6. Service fuses, meters, high-impedance shunt circuits (such as meter potential coils), supply conductors for time switches, surge protective capacitors, instrument transformers, lightning arresters and circuits for emergency systems, fire pump equipment and fire alarms may be connected on the supply side of the disconnecting means.

7. Service disconnecting means must be rated for the load used in sizing the service entrance conductors. Spare capacity or capacity in excess of that determined according to section 2203 does not have to be provided in the service disconnecting means. The judgment of the designer will determine particular needs above minimum.

Note: Local code requirements for service entrances should be checked. The use of six subdivisions of the service disconnecting means, described in 1 above, is often disallowed. A single main service switch is required in many localities.

Overcurrent Protection for Service

Each ungrounded service entrance conductor must be protected by an overcurrent device in series with the conductor. The overcurrent device must have a rating or setting not higher than the allowable current-carrying capacity of the conductor, except as follows:

1. If the service supplies motor loads, the overcurrent device may be rated or set in accordance with the required protection for a feeder supplying several motors or for a feeder supplying a power and lighting load. If only a single motor is supplied, the overcurrent protection should include a value of rating or setting equal to that used to protect the motor branch circuit. (See DISTRIBUTION, Overcurrent Protection).

2. Not more than six circuit breakers or six sets of fuses may serve as overcurrent protection for the service entrance conductors.

3. Each occupant in a multiple-occupancy building must have access to his overcurrent devices. Section 2371-a-4 covers this matter.

4. No overcurrent device may be used in a grounded service conductor, except a circuit breaker which simultaneously opens all conductors of the circuit.

Average Demand Factors for Power Loads

POWER LOAD DEVICE	RANGE OF COMMON DEMAND FACTORS	COMBINED DEMAND AND DIVERSITY FACTORS FOR SIZING SERVICE
Motors for pumps, compressors, elevators, machine tools, blowers, etc.	20 to 60%	40%
Motors for semi-continuous operations in various mills and process plants.	50 to 80%	60%
Motors for continuous operations — as in textile mills.	70 to 100%	90%
Arc furnaces	80 to 100%	100%
Induction furnaces	80 to 100%	80%
Arc welders	30 to 60%	40%
Resistance welders	10 to 40%	30%
Resistance heaters, ovens and furnaces	80 to 100%	90%

High-Voltage (over 600 volts) Services

Code requirements for services exceeding 600 volts are given in sections 2386 to 2392. The provisions apply to primary supply conductors. In cases where primary supply is transformed to a utilization level outside of a building or in a utility transformer vault in the building, the secondary conductors constitute the service conductors.

small kitchen appliances must be allowed for each apartment. In hotels having suites with serving pantries, at least 2000 watts must be allowed for each suite. In non-dwelling occupancies, in which the load represented by general-purpose convenience receptacles is not included with the lighting load as it is in the case of dwelling occupancies, the sum of the design loads used for general-purpose (1½-amp) receptacle branch circuits must be determined and added to the total lighting load. Although the code permits the addition of these loads to connected lighting loads and application of demand factors to the total, it is recommended that these appliance loads be taken at 100% and added to lighting loads only after any demand factors are applied.

Special Loads

Continuing the summation of loads to arrive at a total load to be supplied by the service, there are special loads which must be added for different types of buildings. If the occupancy under consideration is a store, a minimum load of 200 watts must be allowed for each linear foot of show window, measured horizontally along the base. If the building is an apartment house, a total load must be added for electric cooking ranges and appliances used in the building. The total range load in watts for a number of ranges can be determined from Table 29 in Chapter 10 of the code. This table covers ranges and cooking appliances rated over 1,750 watts. Where ranges of less than 8.75 kw are used, the values of load used in calculations should not be less than those given in Column A of the table, to allow future installation of larger ranges.

If fixed appliances (excepting electric cooking appliances and space heating equipment) are part of the load in a building, the sum of their ratings must also be added as part of the total load. The ratings of these appliances should be readily available from the branch circuit design calculations, in which each fixed appliance was provided with a separate individual branch circuit.

For electric space heating in a building, the service entrance conductors must also include an amount of capacity equal to the sum of all of the individual connected loads on the system. This is equal to the sum of the unit heater ratings in watts. Of course, if some of the heating equipment is operating on duty cycle or intermittently or if for any reason all of the units will not be operating simultaneously, a demand factor of less than 100% may be applied to the total heating load. But permission of the code enforcing authority must be obtained.

Adding Motor Loads

The next load which must be accounted for in sizing the service conductors is the motor load. This includes all motors supplied by the service (excepting appliance motors already accounted for). The minimum allowance to make for this load is equal to 125% of the rating of the largest motor supplied plus the sum of the ratings of the other motors. This is the standard feeder calculation for conductors supplying several motors. According to the code, less than 100% demand factor may be applied to the total motor load under certain conditions and with the approval of the authority enforcing the code. Typical conditions permitting use of less than 100% demand for motor load include those cases where reduced heating of conductors results from motors operating on duty-cycle or intermittently or from non-simultaneous operation of all motors. In all such cases, however, the nature and size of the load must be carefully studied. Only sound, conservative engineering analysis is an acceptable basis for the use of demand factor.

Load Totals

Finally, other power loads not previously considered should be added to the total load to be supplied by the service entrance conductors. Here again, 100% demand should be used unless it can be fairly well established that not all of this power load will be operating at the same time.

From the foregoing steps, a total power and lighting load can be developed to use in sizing service entrance conductors. Of course, where separate power and lighting services are used, the above indicated procedure should be divided into two separate procedures. In any case, the load established will be an initial load and in many cases will be the minimum load to use in sizing the conductors. Depending upon the type of building, the size and type of service selected, the size and makeup of the total load and a study of all of these conditions, it will often be advisable and frequently necessary that an allowance for 50% growth in load be included in the service conductors. No strict rule can be applied to this consideration. It is a matter for the individual engineer to use his knowledge and experience in allowing such extra capacity in the service as he thinks best for the particular design. Allowance for load growth should be made for service conductors under the same conditions for which growth capacity would be provided in feeders.

Sum of Feeder Loads

Although the general concept of sizing service presented above is suitable for all types of load concentrations, it is also possible to size service entrance conductors by summing feeder loads which are supplied directly from the service. Particularly in the case of separate power services, it can be found by examination of the conditions that 100% demand of the sum of the feeder loads provides substantial service capacity. And in all cases where feeders have been sized for 100% demand of their branch circuit loads, the same 100% demand would have to be applied to the loads in computing service capacity. The result is that the service capacity works out to be equal to the sum of the feeders. And if feeders were sized for growth in the load, the summation of their carrying capacities would contain appreciable spare capacity.

When a total load—initial and future—has been established for the service entrance conductors, the required current-carrying capacity is easily determined by dividing the total load in kva (or kw with proper correction for power factor of the load) by the voltage of the service. This operation is the same as for feeders and involves the same formulas given in the previous section. From the required current rating of conductors, the required size of conductors is determined. Sizing of the service neutral is also the same as for feeders. Use of multiple conductors per phase instead of a single large conductor, discussed in the previous section, offers clear advantage for makeup of service entrance conductors.

Emergency Electrical Systems

In occupancies where interruption of electrical power supply to the building would result in panic, hazard to life or property or major production loss, provision should be made for emergency supply of power in the event of failure of the regular supply. Such provision may be made by designing an emergency system of distribution and circuits supplied by—

1. **storage batteries,**
2. **emergency generator set,**
3. **separate emergency service or**
4. **subservice tapped ahead of disconnect means for the normal service conductors.**

Code requirements and recommendations for emergency systems are given in Article 700. The scope of the section is described as follows:

"Scope. The provisions of this article apply to the installation, operation, and maintenance of circuits, systems, and equipment intended to supply illumination and power in the event of failure of the normal supply or in the event of accident to elements of a system supplying power and illumination essential for safety to life and property where such systems or circuits are legally required by Municipal, State, Federal or other codes, or by any governmental agency having jurisdiction.

> **"Emergency systems are generally installed in places of assembly where artificial illumination is required, such as buildings subject to occupancy by large numbers of persons, hotels, theaters, sports arenas, hospitals and similar institutions. Emergency systems may provide power for such functions as essential refrigeration, operation of mechanical breathing apparatus, ventilation when essential to maintain life, illumination and power for hospital operating rooms, fire pumps, industrial processes where current interruption would produce serious hazards, public address systems and similar functions.**
>
> **"See NFPA Building Exits Code for specification of locations where emergency lighting is considered essential to life safety."**

High Voltage

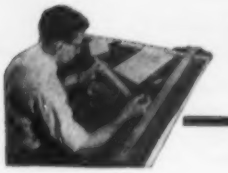
Special design considerations are involved in laying out high-voltage services. The utility will assist the designer in many of the details of such work. General requirements are as follows:

Transformers used indoors in primary supplies rated over 15,000 volts must be installed in transformer vaults as described in sections 4541 to 4548.

A transformer rated up to 15,000 volts may be installed in a building without vault or fire-resistant room provided that (1) it is filled with a liquid that will not burn (askarels), (2) it has mechanical protection, (3) it is properly ventilated, and (4) it is inaccessible to unauthorized persons.

Primary switches, circuit breakers and associated control equipment used in system rated up to 15,000 volts need not be installed in vaults or fire-resistant rooms if the equipment is constructed and approved for use without a vault. Manufacturers' literature covers construction, operation and application of primary switchgear.

In selection of switchgear, the required interrupting capacities will be based on the short-circuit capacity of the supply and the impedance of the transformers. Discussion with utility engineers will assure proper selection of primary switchgear and secondary feeder protection to meet the available short-circuit duty of the supply.

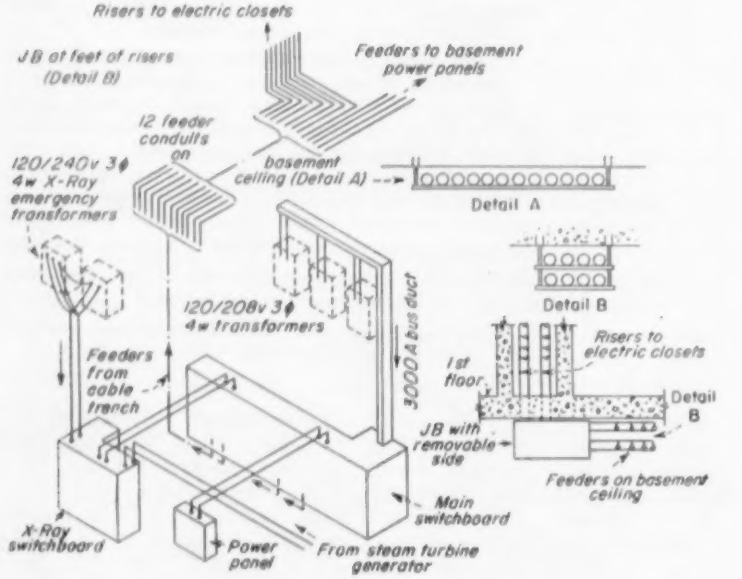


Typical Design Practice

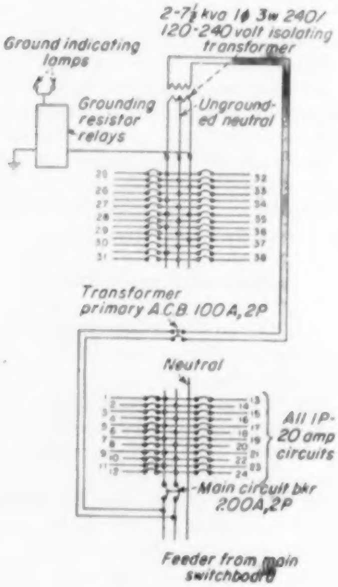
ON THE following pages, various wiring diagrams are given for specific types of buildings. Each diagram should be studied by itself. These diagrams were selected to show modern design trends and to highlight special design details. Taken from job-reports which have appeared in *Electrical Construction and Maintenance* over the past few years and which were developed from first-hand analysis by our editors, the diagrams describe electrical systems in the language of design—lines, symbols and notations. They also indicate the type of diagrammatic presentations to be included in electrical plans. The use of single-line diagrams, riser diagrams and equipment layouts—as shown on these pages—is essential to clearly convey design concepts to the installer.

Hospitals

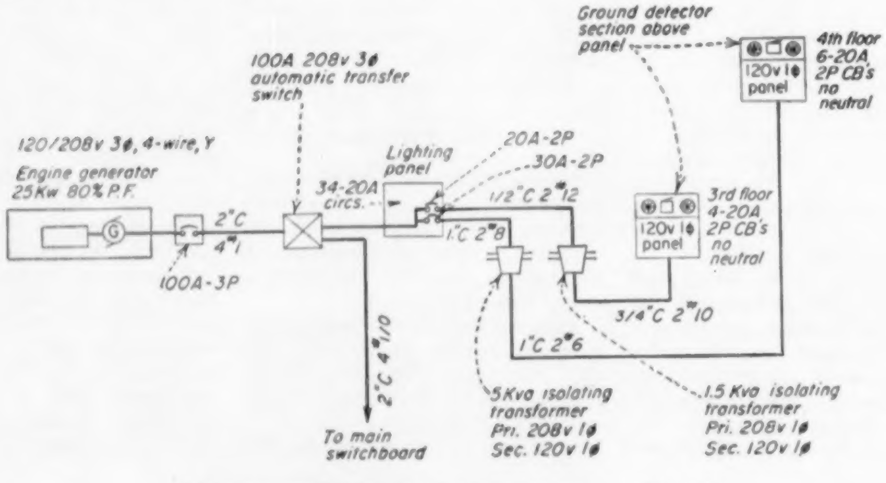
SERVICE TO HOSPITAL



UNGROUNDED CIRCUITS



EMERGENCY POWER LAYOUT



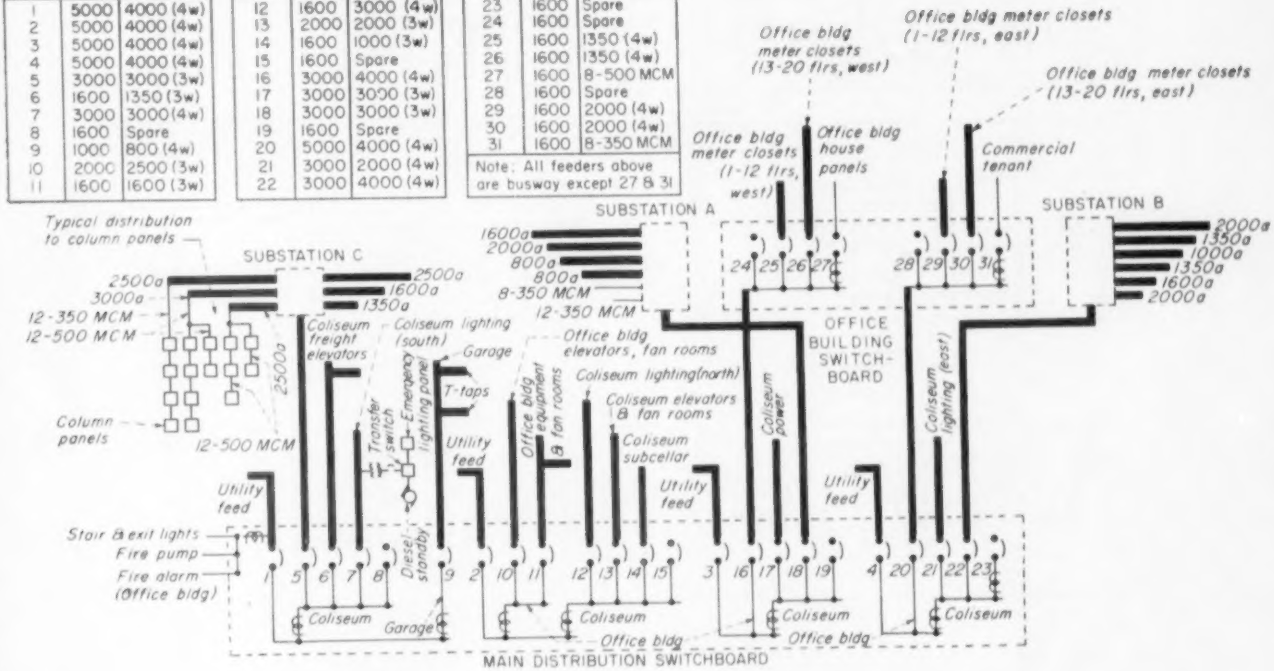
Office Buildings

480/277-VOLT DISTRIBUTION WITH 120/208-VOLT SUBS

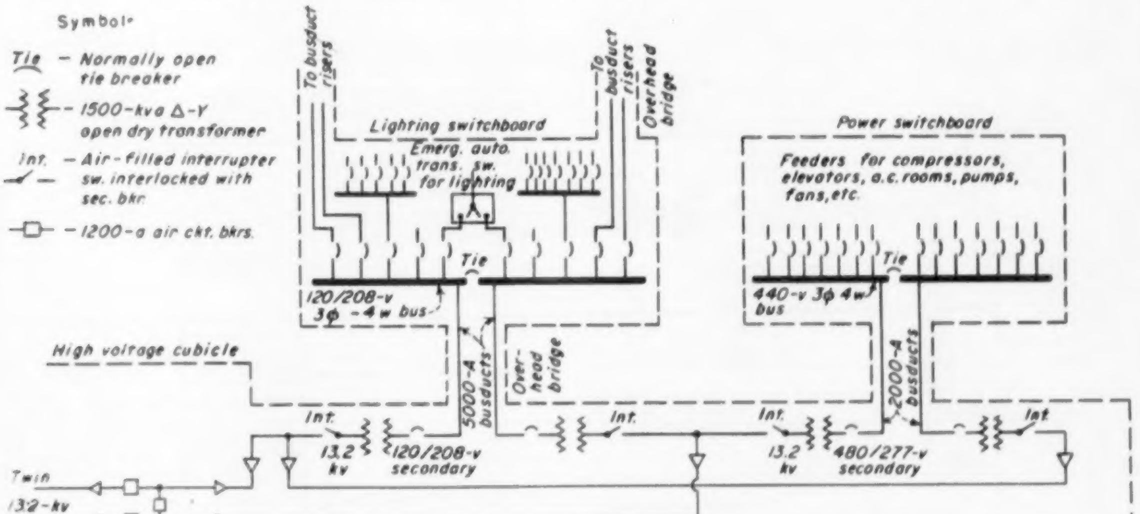
SWITCHBOARD FEEDERS

Feeder	C.B. Frame (amps)	Feeder Rating (amps)
1	5000	4000 (4w)
2	5000	4000 (4w)
3	5000	4000 (4w)
4	5000	4000 (4w)
5	3000	3000 (3w)
6	1600	1350 (3w)
7	3000	3000 (4w)
8	1600	Spare
9	1000	800 (4w)
10	2000	2500 (3w)
11	1600	1600 (3w)
12	1600	3000 (4w)
13	2000	2000 (3w)
14	1600	1000 (3w)
15	1600	Spare
16	3000	4000 (4w)
17	3000	3000 (3w)
18	3000	3000 (3w)
19	1600	Spare
20	5000	4000 (4w)
21	3000	2000 (4w)
22	3000	4000 (4w)
23	1600	Spare
24	1600	Spare
25	1600	1350 (4w)
26	1600	1350 (4w)
27	1600	8-500 MCM
28	1600	Spare
29	1600	2000 (4w)
30	1600	2000 (4w)
31	1600	8-350 MCM

Note: All feeders above are busway except 27 & 31

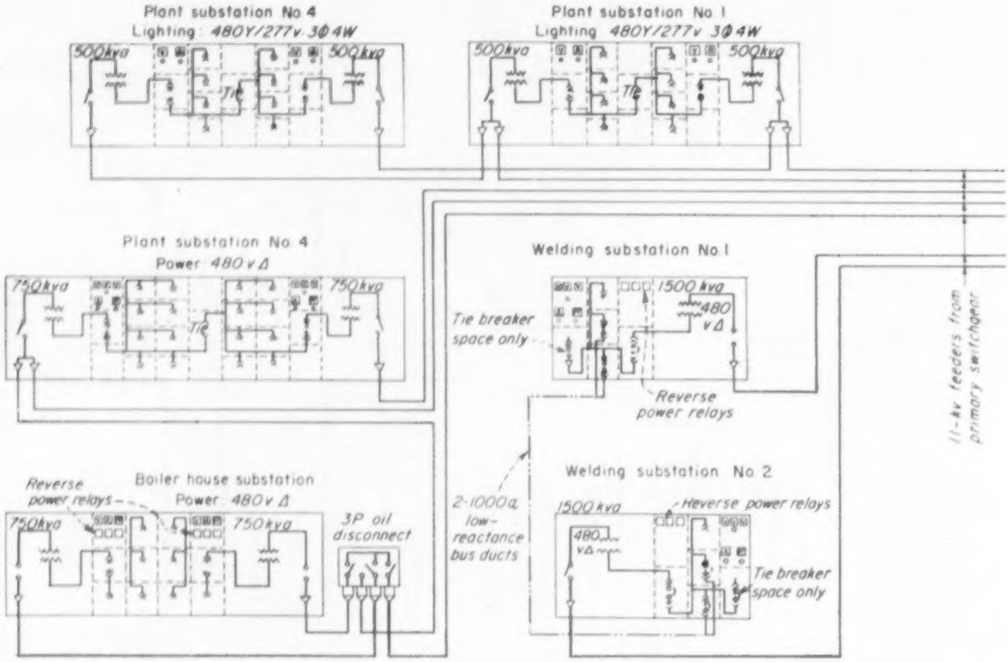


PRIMARY SERVICE TO A LARGE OFFICE BUILDING

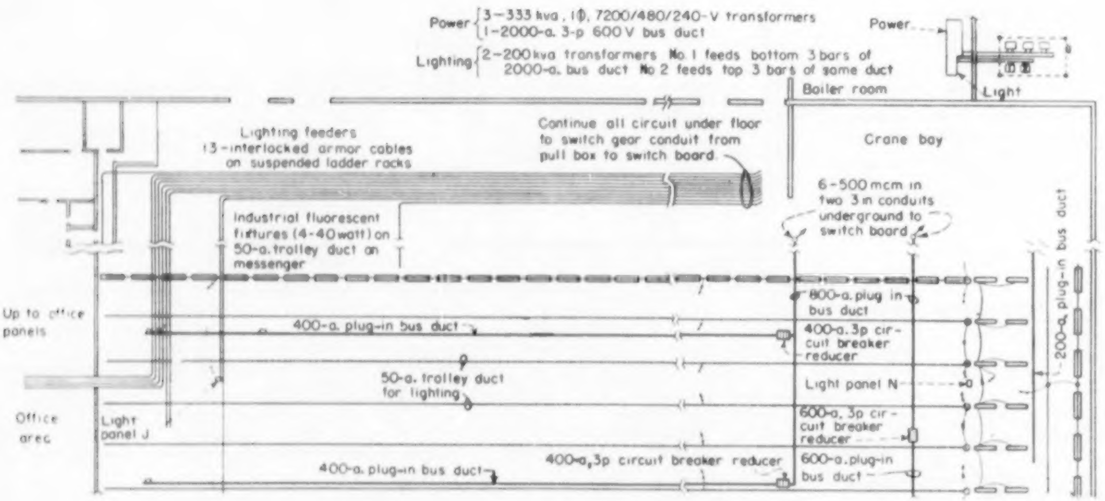


Industrial Plants

DISTRIBUTION FOR AN AUTOMOBILE ASSEMBLY PLANT

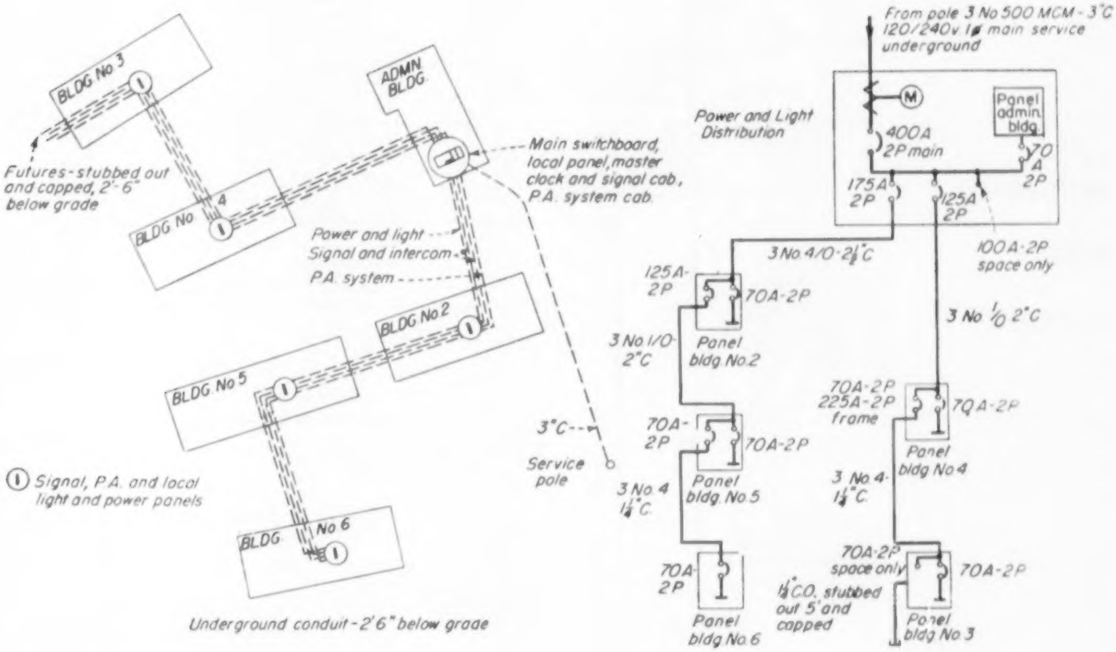


FIVE DISTRIBUTION METHODS IN A MANUFACTURING PLANT

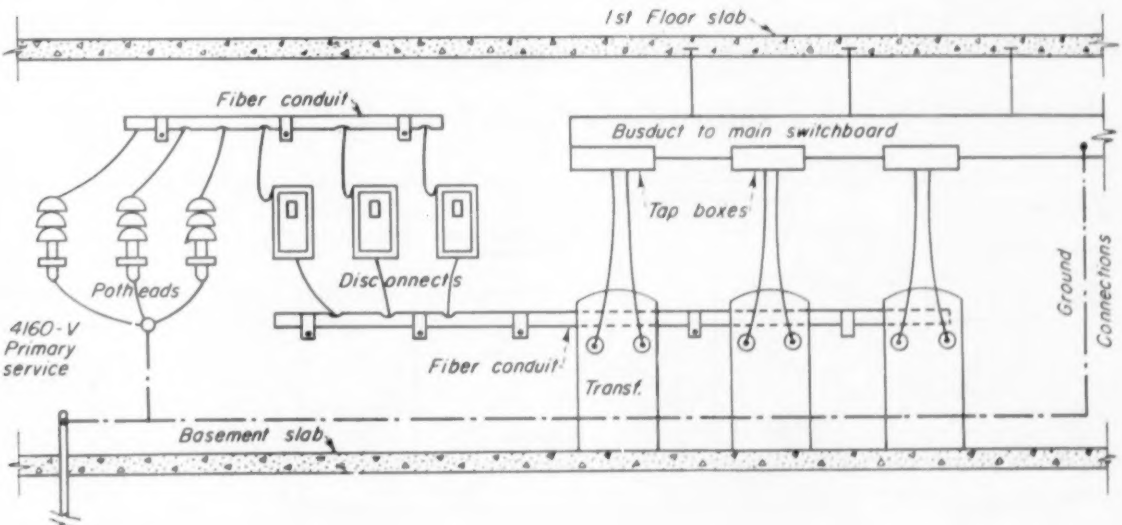


Schools

DISTRIBUTION FOR A MULTI-BUILDING SCHOOL



4160-120/208 VOLTS FOR A LARGE HIGH SCHOOL

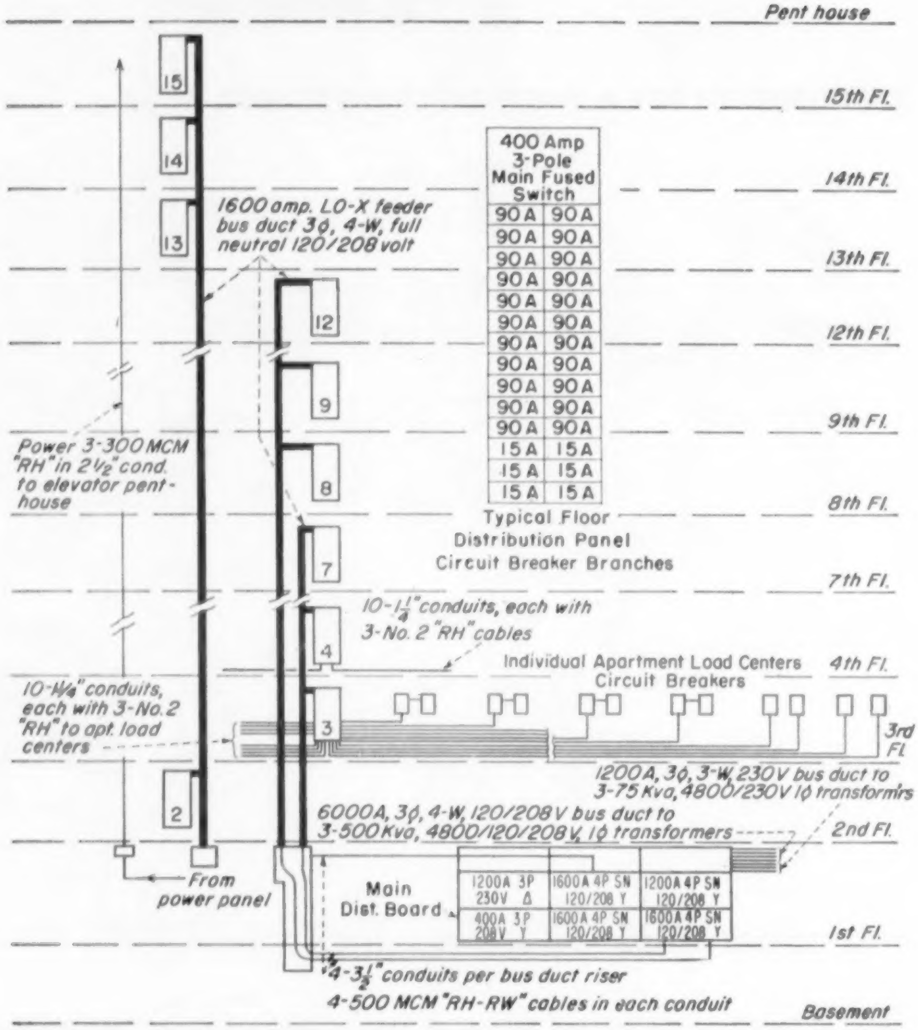


Apartment Houses

MODERN

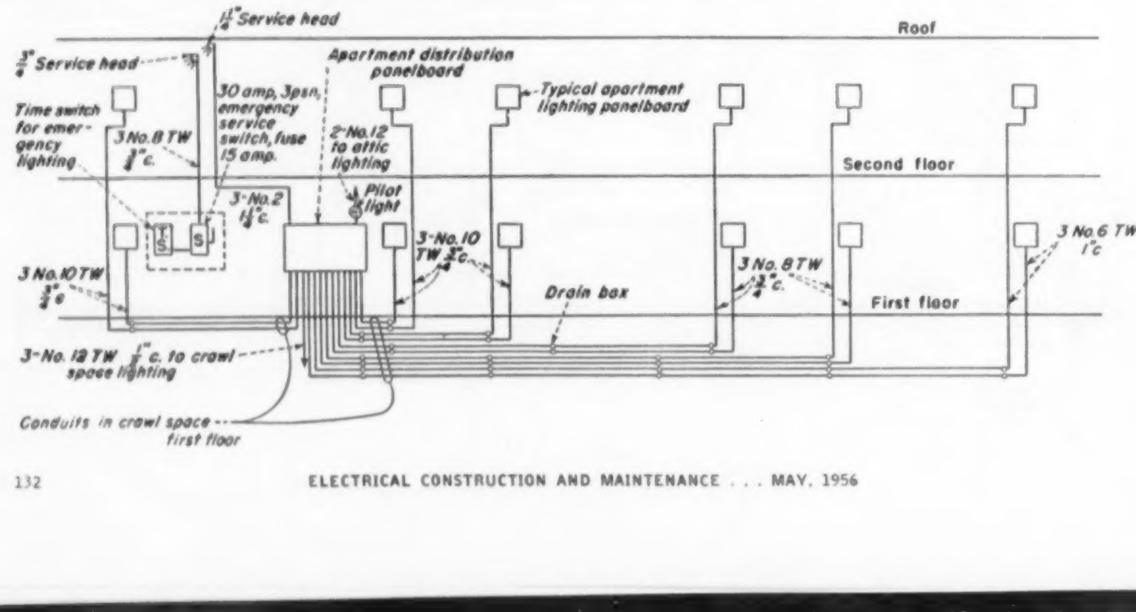
RISER

LAYOUT



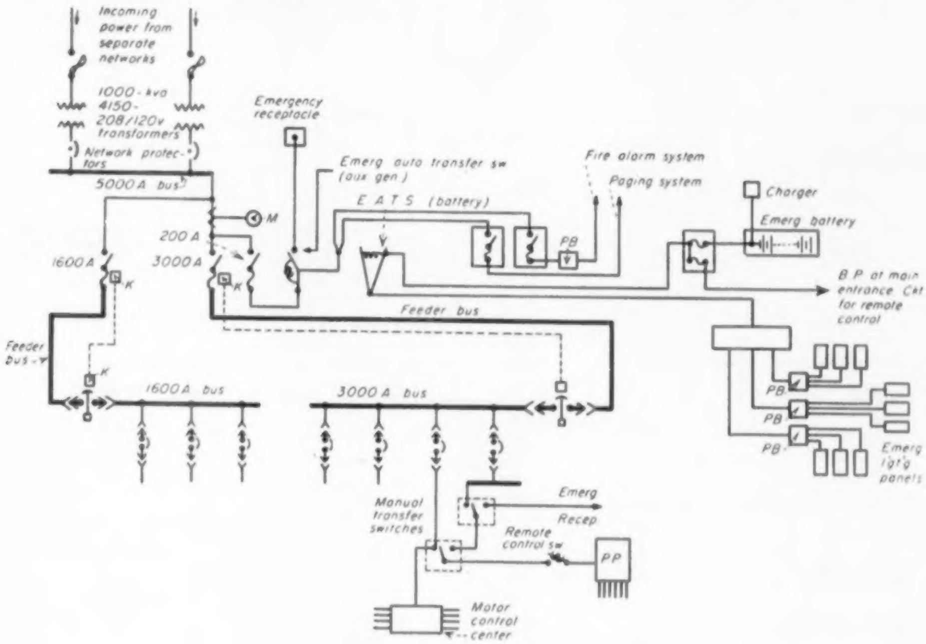
Riser Diagram-Lighting System

RISER DIAGRAM FOR A PROJECT APARTMENT HOUSE

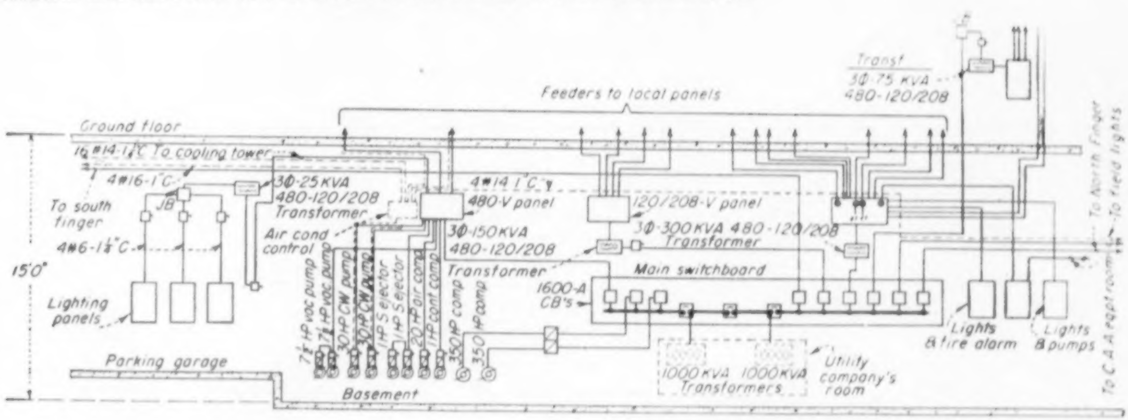


Airport Terminals

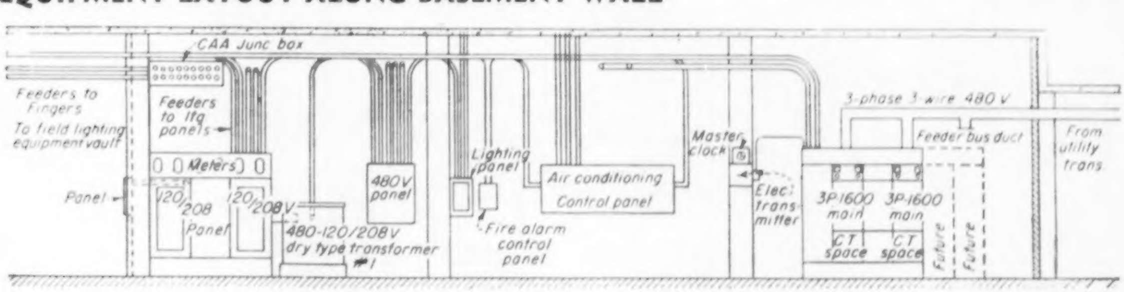
DISTRIBUTION DIAGRAM FOR A TERMINAL BUILDING



RISER DIAGRAM IN A MODERN TERMINAL BUILDING

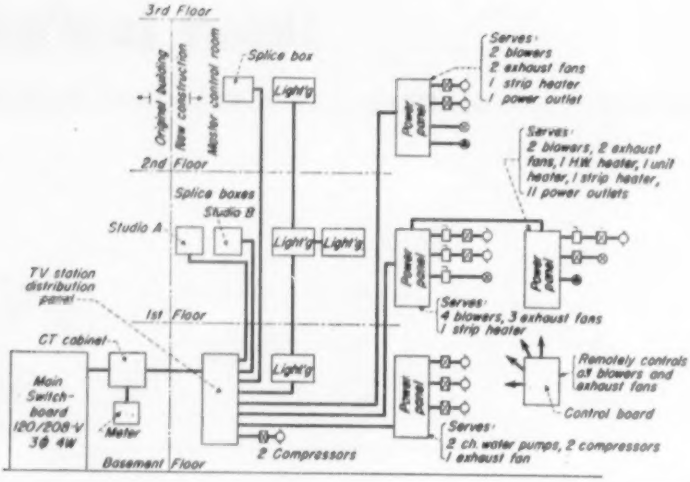


EQUIPMENT LAYOUT ALONG BASEMENT WALL

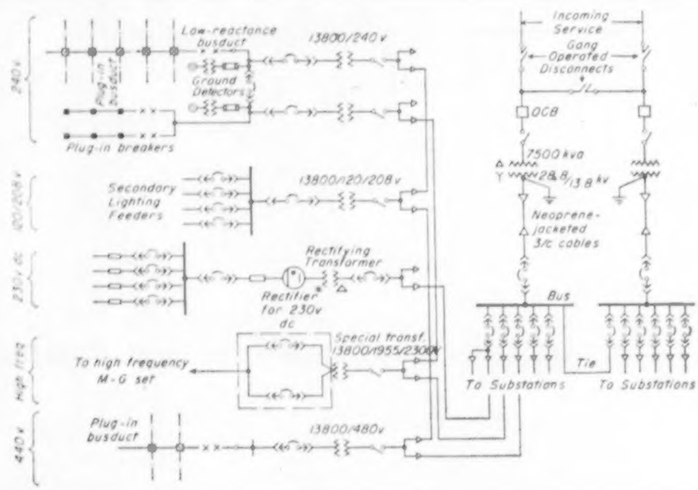


Other Occupancies

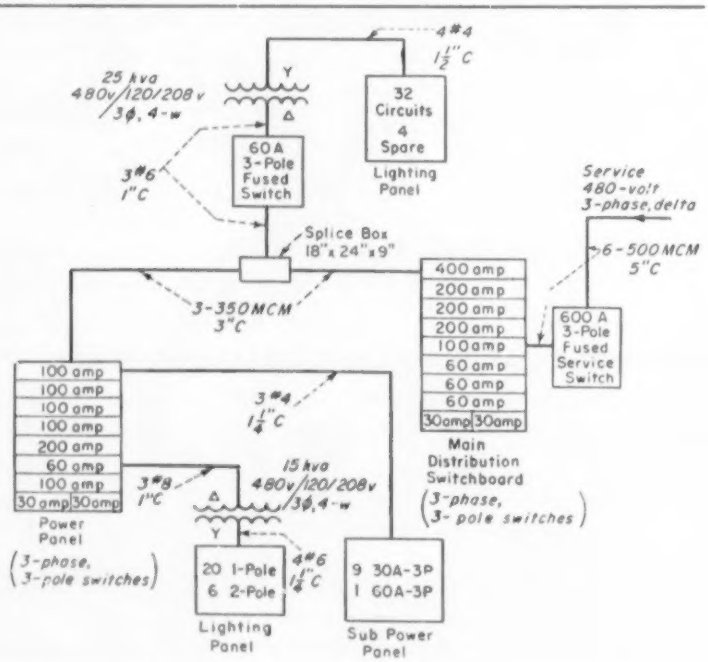
RISER DIAGRAM FOR
A TELEVISION STUDIO



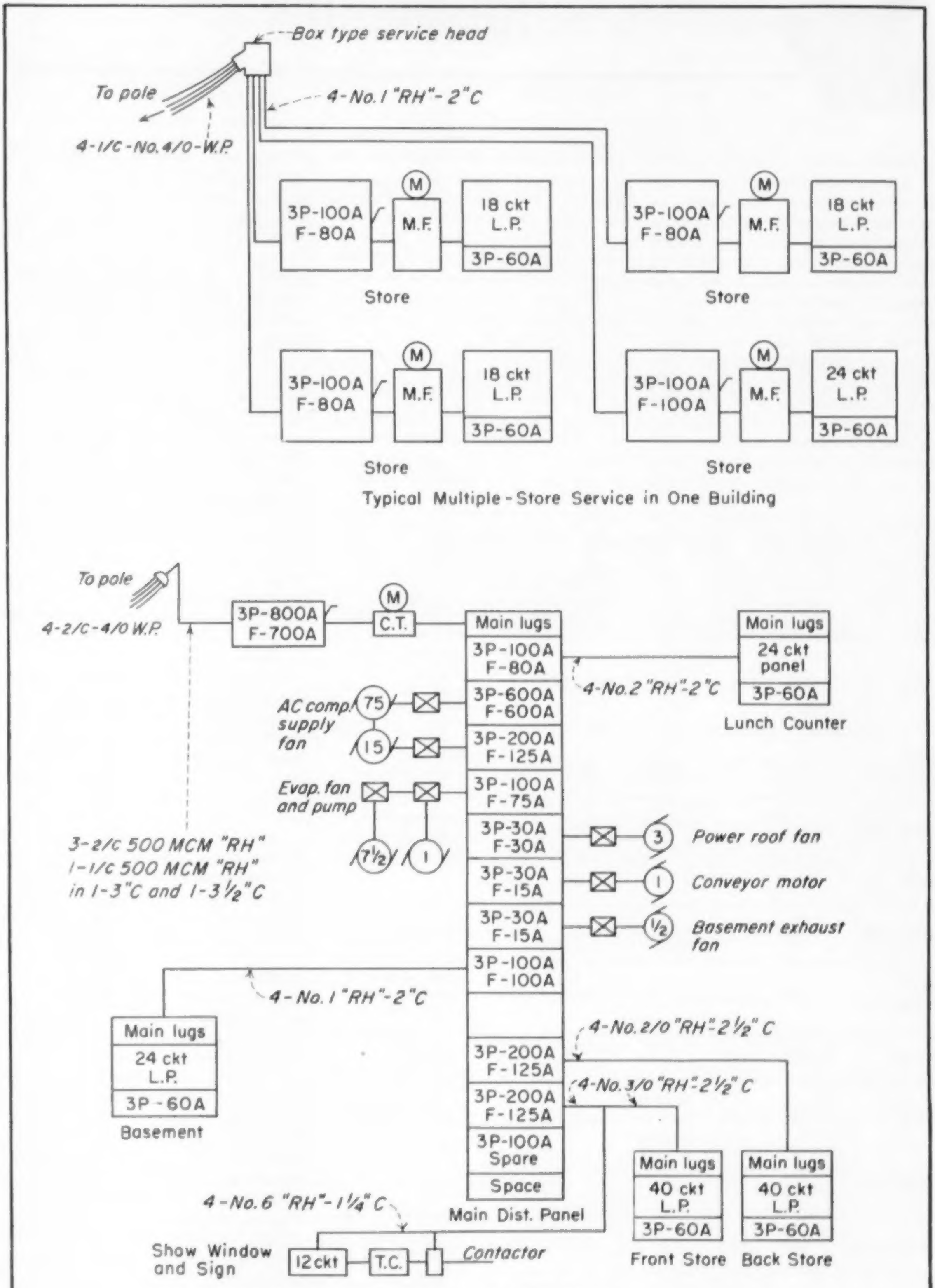
DISTRIBUTION VARIETY
IN A PRODUCTION AND
RESEARCH CENTER



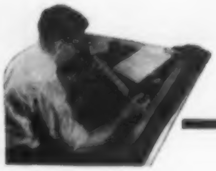
ELECTRICAL SYSTEM
IN A SLAUGHTER HOUSE



SERVICE ARRANGEMENTS FOR SHOPPING CENTERS



Service and Distribution to a Large Store



Residential

DESIGN of an electrical system for a residence follows the same general procedure as used for commercial or industrial design. First, the conditions of load must be analyzed, both present loads (known initial loads) and anticipated future loads. From this study, the number and sizes of branch circuits are determined. Then by combining all of the branch circuit loads into a single load, the requirements of the service entrance to handle the total load can be determined. A full understanding of the methods and procedure for modern residential electrical design is revealed in the following breakdown of these steps. The objective through the complete procedure is to arrive at a load-matched wiring system for the home—a system matched by today's standards to the load represented by the many appliances and utilization devices which make for better living electrically.

Outlets

Based on a study of initial load requirements, the first step in residential design involves layout of outlets for fixed lighting fixtures. This includes kitchen lighting, hall lighting, foyer lighting, bathroom lighting, basement lighting, front and rear door lighting, garage lighting and other fixed lighting units. Such layout may require selection of particular lighting units of various sizes to meet requirements of the builder or home buyer. In indicating these outlets on a set of floor plans for the house, the known or estimated watts to be served by each outlet should be noted.

The next step is provision of receptacle outlets to afford convenient use of electrical appliances in the various areas of the home. Receptacles are available in many sizes and types. There are standard duplex and triplex convenience receptacles, multi-outlet strips and moldings with flexible arrangements of convenience receptacle outlets, weatherproof outlets with protective caps for use on outdoor patios and in other outdoor areas, hanger outlets for clocks and fans, safety receptacles for children's rooms, polarized receptacles to take a grounding connection for appliances, locking-type receptacles to hold plugs in the connected position and special purpose heavy-duty receptacles for electric ranges, dryers, etc.

General-purpose convenience receptacles of the duplex type should be laid out around the perimeters of living room, bedrooms and other general living areas. Spacing of receptacle outlets should be such that no point along the floor line of an unbroken wall is more than 6 ft from a receptacle outlet. Care should be taken to provide receptacle outlets in smaller sections of wall space segregated by doors, fireplaces, bookcases or windows. In hallways, convenience receptacles should be spaced to provide at least one for each 20 ft of wall length.

Convenience receptacles in kitchen, utility or work shop areas should be spaced even closer—one every 4 ft behind work counters and benches. Spacing of receptacle outlets in dining rooms can be 12 ft between receptacles.

CIRCUITS FOR KITCHEN APPLIANCES

	Typical Load in Watts	Volts	Wires	Circuit Breaker or Fuse	Number of Outlets	Notes
RANGE	12000	120/240	3- #6	50-60A.	1	Use of more than one outlet is permitted, but not recommended.
OVEN (Built in)	4500	120/240	3- #10	30A.	1	Appliance may be direct connected.
RANGE TOP	6000	120/240	3- #10	30A.	1	Appliance may be direct connected.
RANGE TOP	3300	120/240	3- #12	20A.	1 or more	
DISHWASHER	1200	120	2 #12	20A.	1	These appliances may be direct connected on a single circuit. Grounded receptacles required, otherwise.
WASTE DISPOSER	300	120	2 #12	20A.	1	
BROILER	1500	120	2 #12			Heavy duty appliances regularly used at one location should have a separate circuit. Only one such unit should be attached to a single circuit at a time.
FRYER	1300	120	At Least Two Kitchen Appliance Circuits	20A.	2 or more	
COFFEEMAKER	1000	120				
REFRIGERATOR	300	120	2 #12	20A.	2	Separate circuit serving only refrigerator and freezer is recommended.
FREEZER	350	120	2 #12	20A.	2	

Other convenience receptacles should be laid out for specific areas of the home—the bathroom, the pantry, refrigerator alcove and laundry area. Number and positioning of these outlets must be determined by the designer in accordance with the particular architectural layout of the areas and with the nature of the work or activity involved.

Over and above general-purpose outlets and convenience receptacles, special-purpose outlets must be laid out to serve large known or anticipated appliances. The exact number of these outlets will vary with extent of electrical utilization. However, special-purpose outlets must be provided for such appliances as electrical cooking appliances, electric clothes washers, electric dryers, electric ironers, dishwashers, food waste disposal units, water heaters, electric heaters, air conditioners, heat pumps, fuel-fired heating units and other specific load devices. These appliances and devices should be either plug-connected to their supply circuits or direct-connected, as indicated in the accompanying table of residential circuits.

APPLIANCE CIRCUITS

Load Devices	Typical Load in Watts	Volts	Wires	Circuit Breaker or Fuse	Number of Outlets	Notes
Circuits for Laundry Areas						
IRONER	1650	120	2 #12	20A.	1	Grounding type receptacle required.
WASHING MACHINE	1200	120	2 #12	20A.	1	Grounding type receptacle required.
DRYER	5000	120/240	3 #10	30A.	1	Appliance may be direct connected — must be grounded.
Circuits for Other Loads						
HAND IRON	1000	120	2 #12	20A.	2 or more	
WATER HEATER	3000					Consult Utility Co. for load requirements
WORKSHOP	1500	120	2 #12	20A.	2 or more	Separate circuit recommended.
PORTABLE HEATER	1300	120	2 #12	20A.	1	Should not be connected to circuit serving other heavy duty loads.
TELEVISION	300	120	2 #12	20A.	2 or more	Should not be connected to circuit serving appliances.

UNIT AIR CONDITIONERS

Size of Air Conditioner	Average Wattage	Circuits Required	Size of Each Circ.	Number of Outlets	Remarks
Air Conditioner ¾ hp	1200	Separate Circuit	2#12 120-v	1	Use of 3-wire, 120/240-volt circuits to unit conditioners offers circuit flexibility for 120 or 240 volts
Air Conditioner 1½ hp	2400	Separate Circuit	3#12 120/240-v	1	

Circuits

Circuits used to supply residential electrical loads are divided into six basic types as follows:

1. 120-VOLT GENERAL PURPOSE CIRCUIT—two No. 12 wires—has maximum design capacity of 2000 watts. Circuits of this type must be provided to handle the load of fixed lighting units throughout the house and the general-purpose convenience receptacles in areas other than the kitchen, dining, pantry, breakfast room, utility or laundry areas.

2. 120-VOLT APPLIANCE CIRCUIT—two No. 12 wires—has maximum design capacity of 2000 watts. At least two such circuits must be provided to handle the appliance load in the kitchen and dining areas. All receptacles in these areas must be connected to such a circuit, excepting clock outlets.

3. 120-VOLT SPECIAL PURPOSE CIRCUIT—two No. 12 wires—has maximum design capacity of 2000 watts. This type of circuit is used to serve a single outlet (plug- or permanently-connected) for an individual appliance or load device.

4. 240-VOLT SMALL CIRCUIT—three No. 12 wires—has maximum design capacity of 4000 watts. This is a special-purpose circuit to serve an individual equipment load which is rated at less than 16 amps at 240 volts.

5. 240-VOLT MEDIUM CIRCUIT—three No. 10 wires—has maximum design capacity of 6000 watts. This is a special-purpose circuit to serve an individual equipment load which is rated from 16 to 24 amps at 240 volts.

6. 240-VOLT LARGE CIRCUIT—three No. 6 wires (neutral may be smaller)—has maximum design capacity of 10,000 watts. This is a special-purpose circuit to serve

10 Steps to Take in Calculating Size of Service Entrance Conductors

STEP 1. Calculate the load of general lighting and general-purpose receptacle outlets — to be served by 120-VOLT GENERAL PURPOSE circuits. For each 500 sq ft of floor area in the house (excluding porches, garages, unused spaces and unfinished areas, etc.), allow one such circuit. Allow an extra circuit for any part of 500 sq ft left over. Multiply the required number of circuits by 2000 to get the total load in watts. (It should be noted that the same figure could be arrived at by multiplying the total square feet of floor area by 4 watts per-sq-ft.)

STEP 2. Add the total circuit capacity — in watts — allowed for the appliance load in the kitchen, dining room, pantry, laundry and utility area, to be served by 120-VOLT APPLIANCE circuits. This watts total can be obtained by multiplying the number of such circuits laid out in branch circuit design by 2000. Or an assumed load of 4000 watts (two appliance circuits) can be used when the exact number of such circuits is not known.

STEP 3. Take 3000 watts of the sum of Steps 1 and 2 at 100% demand.

STEP 4. Add to this figure 35% (demand) of the remainder from the first three steps.

STEP 5. The sum of Steps 3 and 4 is the amount of capacity which must be provided in the service entrance conductors to supply the general lighting and general-purpose receptacle loads.

STEP 6. Add 8000 watts for an electric range (not over 12 kw rating). If the electric cooking appliances consist of a built-in oven and range top(s), Table 29 in Chapter 10 of the code must be consulted to get the proper demand load.

STEP 7. Add together the rated watts of all fixed appliances to be served by individual circuits not previously accounted for in the calculation. If both electric heating and air conditioning are to be used in the house, the rating in watts of only the larger of the two loads need be used in this total. This is, of course, due to the non-simultaneous use of the two facilities.

STEP 8. Get the total of: the general lighting and general-purpose receptacle load (from Step 5.); the electric range demand load (from Step 6.); and 100% of the sum of fixed appliance loads (from Step 7.).

STEP 9. Divide this grand total of watts by 240 (for 120/240-volt, 3-wire, single-phase service) to get the required ampere rating of the service conductors.

STEP 10. From Table 1 in Chapter 10 of the code, select the size of conductors which have the required current-carrying capacity. Table 4 in Chapter 10 gives the required size of conduit to carry the service entrance conductors.

one or more electric cooking appliances rated from 24 to 44 amps. at 240 volts.

These circuits are presented in this form to afford a quick and ready way to think of circuit requirements. The intent and logic behind such a breakdown of circuit types should be fully understood to assure proper use of the information. The circuits may vary somewhat from the indicated makeup for particular applications and depending upon the type of wire or cable assembly used for the circuiting. Ground wires must be added where necessary, and the use of 3-wire circuits instead of multiple 2-wire circuits—such as a single, 3-wire 120/240-volt circuit for two kitchen appliance circuits—offers wiring economy in many cases. The design ratings given are based on 80% loading of circuits to assure minimum voltage drop on long circuits and to provide a measure of spare capacity. Best design practice dictates the use of 50% fixed and regular-duty loading of general-purpose circuits to allow full and flexible use of plug-connected portable appliances which are used for short but continuous periods—like hair dryers, pants pressers, electric hand irons, bottle warmers, vacuum cleaners and similar work appliances.

Circuit Requirements

The requirements for branch circuiting—as set forth early in this report—cover sizing of circuit conductors, selection and sizing of overcurrent protective devices (selected with the panelboard to be used) and loading of circuits. Depending upon the general lighting load, the number of general-purpose receptacle outlets and the number and types of electrical appliances to be used, circuits can be laid out on the plans—using standard symbols to show the various circuits, outlets, switch legs, home runs and other data essential to properly inform the installer of the finished system the designer has in mind.

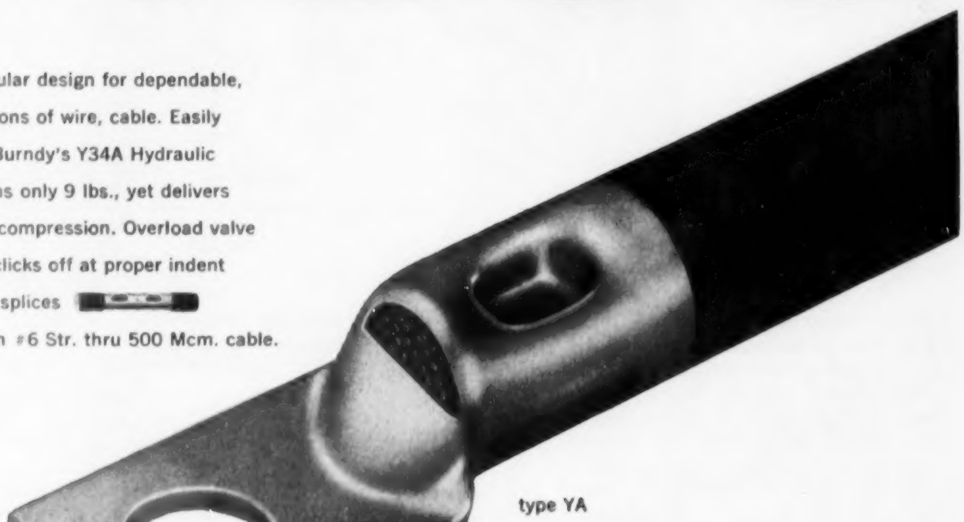
At least one 120-volt general-purpose circuit should be allowed for each 500 sq ft (or fraction thereof) of floor space in the house (excluding porches, etc.). This works out to 4 watts per-sq-ft of floor area. And this is circuit capacity for general lighting and

"that 'click' means it's right..."

"and these HYPRESSES sure save time."

HYLUG

One piece, tubular design for dependable, rapid terminations of wire, cable. Easily installed with Burndy's Y34A Hydraulic Hypress. Weighs only 9 lbs., yet delivers 18,000 lbs. of compression. Overload valve automatically clicks off at proper indent depth. Installs splices or terminals on #6 Str. thru 500 Mcm. cable.

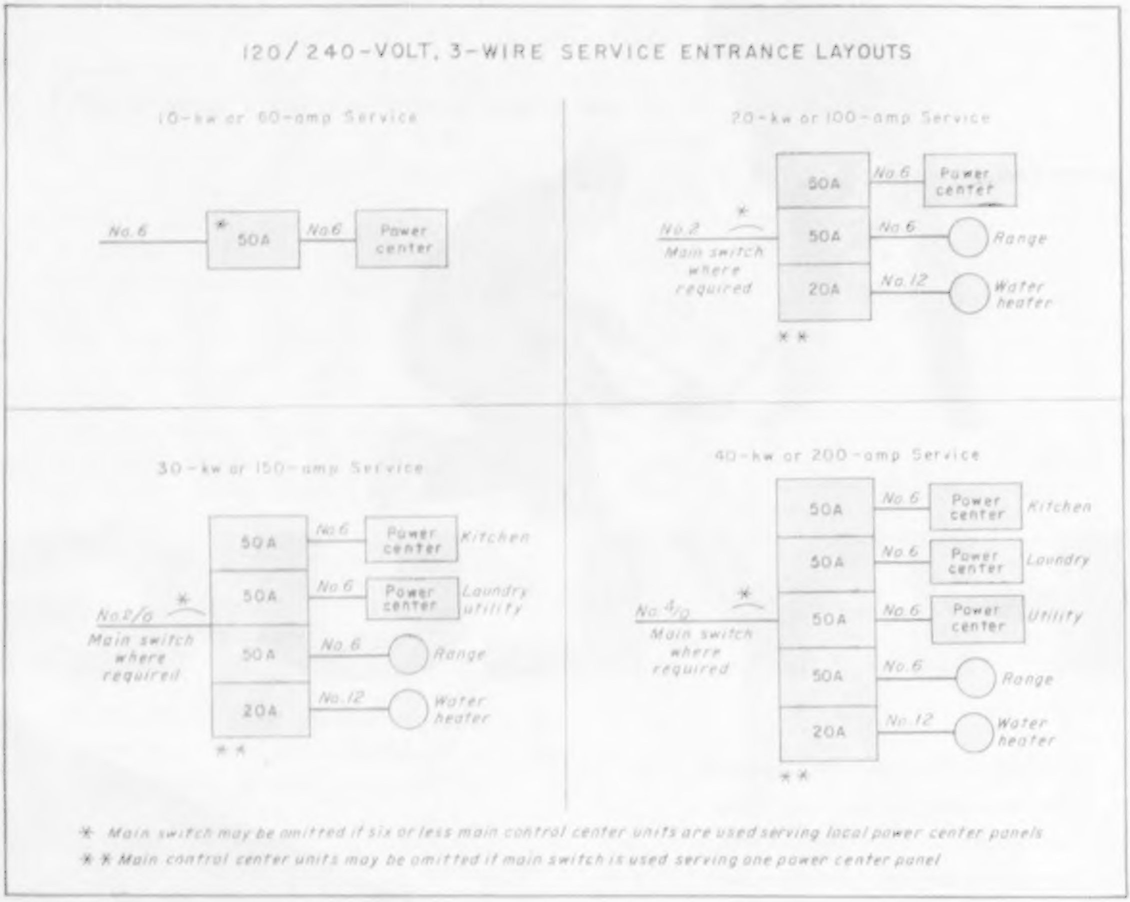


type YA

BURNDY

56-2

Norwalk, Connect. • Toronto, Canada • Other Factories: New York, Calif., Toronto • Export: Philips Export Corp.



general-purpose receptacle outlets. This much capacity is a minimum recommended amount. In some cases, the use of extensive general lighting and special lighting effects throughout the house will require greater circuit capacity for the load. In such cases, the loads should be broken down and circuited carefully to assure proper loading of circuits. In any case, however, the total general load must be divided among the number of general-purpose circuits used, laying out back-to-back outlets in interior partitions and utilizing three-wire circuits to split-wired receptacles to effect balanced loading. By laying out each circuit to serve a few of the outlets in each of several rooms, conforming actual positioning of receptacle outlets to keep each circuit lightly loaded when heavy utilization exists in a single room, the possibility of overloading either side of the 3-wire system can be virtually eliminated.

Appliance Circuits

In the kitchen and dining room areas (including the pantry and breakfast room), at least two 120-volt appliance circuits must be provided. One or more such circuits must also be provided for the laundry area, depending upon the location and the total load; and the utility or work room should have one or more circuits of this type. Other appliance circuits are described on the previous pages.

Other circuit requirements for a typical house are given in the accompanying table which gives complete data for each type of appliance or device.

Service Entrance

Calculation of the size of service entrance conductors and layout of the service equipment and distribution equipment (either a single load center in the basement or garage, combined with or adjacent to the service equipment, or one or more local power centers on the upper floors of the house in addition to the service entrance panelboard) are made from study of the load and branch circuit provisions. A straightforward procedure for sizing service entrances is given in an accompanying box. This procedure is no substitute for engineering design of the branch circuit system supplied from the service entrance. The procedure requires careful and knowing insertion of data based on load conditions.

HEAVY DUTY Permacel Plastic Electrical Tape is excellent for all jobs requiring high dielectric strength and good conformability. Will not support combustion and is ozone-resistant. Here, used as a bus bar covering, Permacel 30 is superior for all types of electrical insulating, splicing and protecting.

SELF-STICKING

PERMACEL® TAPE

From Permacel Research . . . the right tape for any job. Write Permacel Tape Corporation, New Brunswick, N.J.

a Johnson & Johnson company

Lighting Systems

THE first step in designing a lighting system is to make a thorough analysis of the lighting problem. This analysis will include the determination of the seeing tasks which will obtain, of the desired lighting result, and of all physical and structural details of the area, or areas, to be lighted.

Seeing tasks and desired lighting results will depend on the type of work or activity to be carried on in the areas. If the areas are to be used for manufacturing, it will also be necessary to determine the type of production which will be done in each area, in order to more accurately appraise the seeing task. If the areas are to be used for offices, or drafting rooms, or school classrooms, as much information should be obtained about the specific work to be done as possible for the same reason. Or, if the areas are to be used for stores, banks, hospitals, etc., determine the exact seeing problems for each specific room, or area. This information will be needed as a guide in the selection of the proper lighting intensity, and of a suitable type of lighting system to provide the best possible lighting result.

Physical considerations include area dimensions, ceiling heights, color and reflectances of ceilings, walls, floors, and furnishings or machinery, the degree of light interference by machines, furniture, workers, etc., and in the case of relighting, the existing wiring capacity. Physical considerations also include structural elements and architectural detail, especially where concealed equipment, is involved.

Once the type of activity or work has been determined, it will be possible to classify this activity or work according to the degree of severity of the visual tasks. This in turn will enable the lighting designer to select a suitable range for the lighting intensity which should be provided for each activity or type of work, and for each area of the project. Suitable levels of illumination have been determined through experience, study, and research, and listed in chart form (chart above).

For general lighting, intensities up to 150 footcandles are recommended. Where seeing tasks involving considerable length of time are involved, even though the seeing tasks are not very difficult, values below ten footcandles should generally be avoided. Ten to 35 footcandles are considered adequate for general rough work, such as the lighting of restaurants, passage-

RECOMMENDED LEVELS OF ILLUMINATION

TYPICAL VISUAL TASKS

SEVERITY OF VISUAL TASKS*

SPECIAL APPLICATIONS – **1000 footcandles and above.** Major surgery. Special display lighting. Combating show window reflections in daytime.

MOST DIFFICULT – **500 to 1000 footcandles.** Show window and display lighting. High-lighting. Color identification. Special inspection.

VERY DIFFICULT – **250 to 500 footcandles.** Extra fine assembly. Fine inspection. Color work. Display lighting. Show window lighting.

DIFFICULT – **125 to 250 footcandles.** Fine assembly. Fine machining. Inspection. Show windows. Counter displays. Fine drafting. Stencil cutting.

AVERAGE – **60 to 125 footcandles.** Proofreading. Show cases and wall cases. Counter displays. Drafting. Type setting. General assembly. Automatic machinery.

– **30 to 60 footcandles.** General fabrication. Sewing on light goods. General merchandising. Desk work. Classrooms. Laboratory work. Library reading rooms.

CASUAL – **15 to 30 footcandles.** General processing. Woodworking. Cafeterias. Pressing. Circulation areas. Casual desk work. Conference rooms. Auditoriums.

ROUGH – **7 to 15 footcandles.** Auditoriums. Dining areas. Reception rooms. Stock rooms. Wash rooms. Loading. Packing. Rough work. Foundries. Shipping.

VERY ROUGH – **7 footcandles and less.** Hallways and corridors. Passageways. Outdoor storage. Circulation areas. TV viewing. Dining. Night clubs.

ILLUMINATION IN FOOTCANDLES: 1280, 1000, 800, 640, 500, 400, 320, 300, 200, 160, 100, 80, 60, 40, 30, 20, 15, 10, 5

*Arbitrary classification, but based on assumption that any visual task that is twice as difficult as another requires twice as much light for equal seeing ease.

Recommended Interior Reflectances

Surface	Reflectance Range (%)
Ceiling	75 — 90
Upper Walls	50 — 65
Trim	40 — 50
Machines	30 — 40
Lower Walls	30 — 50
Furniture	25 — 40
Floors	15 — 30

Recommended Brightness Ratios for Interior Lighting

In Visual Field . . .	Ratios
a. Between visual tasks and adjacent surroundings (e.g. — white paper and desk top)	1 to 1/3
b. Between visual tasks and more remote darker surfaces (e.g. — white paper on desk and floor)	1 to 1/10
c. Between visual tasks and more remote brighter surfaces (e.g. — white paper on desk and luminaires)	1 to 10
d. Between luminaires and adjacent surfaces in normal field of view	20 to 1
e. Anywhere within normal field of view (e.g.—between luminaire and floor)	40 to 1

ways, foundries, and of packing, loading and shipping departments. But as the seeing task becomes more critical, as in offices, banks, stores, classrooms and drafting rooms, lighting intensities of from 35 to 100 footcandles and above are recommended.

Supplementary lighting is normally used to provide lighting levels in excess of 100 footcandles. Such intensities are desirable in display lighting in stores and show windows, for sewing on dark materials, for inspection, and for assembly of fine parts, color work and color identification. Supplementary lighting will usually be required for critical size of the seeing task, and under average to poor contrast conditions. Caution is urged in the use of supplementary lighting, as the introduction of high levels of illumination over a relatively small area may become a source of glare.

The age of employees or people occupying an area is also an important consideration when selecting the lighting intensity for any specific work area. More light is required for equal ease in seeing for older persons, since eyes become less responsive with age and higher lighting levels will help these older persons to see faster and more accurately.

On relighting projects the lighting designer should carefully survey all existing structural details and be sure the lighting system he recommends is feasible and practical, and that the luminaires and equipment can be installed in the locations indicated.

Selection of Lighting System

Lighting systems are classified according to type of light distribution, and to type of luminaires and lighting equipment. The five basic types are direct, semi-direct, general diffuse, semi-indirect, and indirect. The light distribution pattern from practically any type of luminaire or lighting equipment falls into one of these basic types.

Luminaires and lighting equipment are further described as residential, commercial, industrial, or institutional, according to general application, and as ceiling mounted, suspended, ornamental, concealed, recessed, and architectural, according to method of installation.

The lighting engineer has at his disposal today the greatest array of light sources, luminaires, lighting units, reflectors, wiring strips, lenses, diffusers, louvers, color devices, etc. in the history of lighting. Selection of the proper units and devices to accomplish any predetermined lighting result, or lighting effect, is more or less of a nut-and-bolts problem, and these units and equipments are available on a mass produced, inexpensive basis—not as custom-made high-priced equipment. The lighting engineer creates a custom job of these mass-produced units and components, however, by tailoring their combination and assembly to meet the individual requirements of each customer.

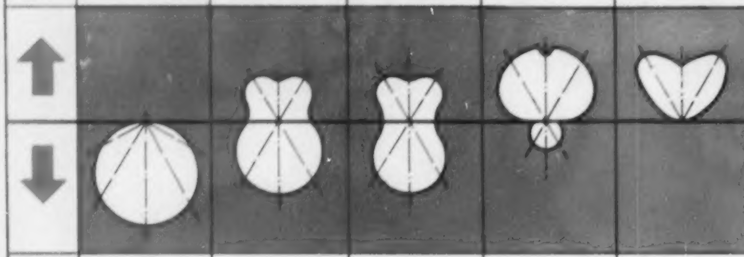
Once an analysis of the lighting problem has been completed, and the type of lighting results required is known, the lighting designer begins to select an appropriate type lighting system step-by-step, and component-by-component. First, he determines which type of light source will provide a suitable color quality of illumination. Next, he considers which basic type of lighting system will provide the quality of illumination that is needed, efficiently. Then he considers what type of luminaires or equipment will fit into the structural details of the building, what type of equipment layout fits into the area, and how the luminaires and the equipment layout will conform with the architectural design and appearance of the structure. These steps may be exploratory on a mental basis, or may be set down as notes for a trial and error analysis. By this process, various systems and components may be eliminated until only two or three types of equipment seem to be suitable. Then preliminary layouts and calculations are made on each type of equipment until one system emerges which best meets all requirements.

Some of the factors to be considered in selecting the light source, or sources, for any specific lighting application include color quality of the light produced, total lumen output per lamp, physical size of the lamp, lamp life, lumen depreciation throughout life, efficiency of converting electrical energy into light, stroboscopic effect, how hot the lamp gets when burning, and the effect of ambient temperature surrounding the lamp on its light output.

There are three types of light sources—incandescent, fluorescent, and mercury. Between these three types it is possible to find a size and shape to meet almost any lighting problem presented. Some of the more popular types used for general lighting purposes are listed in the table (next page), with columns showing average light output, and operating life, two important factors to be considered when selecting the lamps to be used. Every lighting engineer should, of course, have in his files for quick reference full information on complete listings of all three types of light sources.

Incandescent lamps are point sources of light, and light distribu-

LIGHTING SYSTEMS CLASSIFICATION					
SYMBOL	Type D	Type SD	Type G	Type SI	Type I
UP	0-10 %	10-40 %	40-60 %	60-90%	90-100 %
DOWN	90-100 %	60-90 %	40-60 %	10-40 %	0-10 %
TYPE	Direct	Semi-direct	General diffuse	Semi-indirect	Indirect



Average Light Output and Operating Life for Typical Light Sources

INCANDESCENT LAMPS

Lamp Designation	Rated Life (Hours)	Initial Output (Lumens)	Mean Output (Lumens)	Burnouts Per BLH•
100-watt A21	750	1,630	—	—
150-watt A23	750	2,700	—	—
200-watt A25	750	3,700	3,500	381
300-watt PS35	1,000	5,650	5,100	196
500-watt PS40*	1,000	11,200	10,200	98
750-watt PS52*	1,000	17,100	15,800	63
1000-watt SS52*	1,000	23,400	21,300	47
500-watt R52	2,000	7,500	6,900	73
750-watt R52	2,000	12,500	10,000	50

*Coiled-coil filament axially mounted.

FLUORESCENT LAMPS

Lamp Designation	Rated Life (Hours)*	Initial Output (Lumens)	Mean** Output (Lumens)	Burnouts Per BLH•
F40T12/CW	7,500	2,500	2,150	62
F40T12/D	7,500	2,300	2,000	67
F90T17/CW	7,500	5,150	4,250	31
F90T17/D	7,500	4,800	4,000	33
F48T12/CW/RS (800 ma)	7,500	3,100	—	—
F72T12/CW/RS (800 ma)	7,500	4,800	—	—
F96T12/CW/RS (800 ma)	7,500	7,250	6,150	22
F48T12/CW Slimline	7,500	2,300	2,000	67
F96T12/CW Slimline	7,500	5,050	4,500	30

*Based on 3 burning hours per start.
**Approximate mean output at 40% life.

MERCURY VAPOR LAMPS

Lamp Designation	Rated Life* (Hours)	Initial Output (Lumens)	Mean Output (Lumens)	Burnouts Per BLH•
H250A5	6,000	11,000	8,900	18.7
H400E1	6,000**	21,000	16,400	10.2
H400J1	6,000**	20,000	15,600	11.7
H400R1	6,000**	18,000	14,900	11.2
H400RC1	6,000**	20,500	17,000	9.8
H1000A15	6,000	54,000	35,100	4.8
H3000A9	6,000	132,000	103,000	1.6

*Rated life data shown are averages from tests of lamps burning five hours per start in appropriate industrial type reflectors.
**Designates economic life of the lamp under typical average operating conditions.
•Average lamp burnouts per billion lumen hours (calculated).

tion can be controlled fairly accurately. Rated life is low, averaging about 1000 hours actual burning. The lamps get quite hot when burning, but their light output is not affected by changes in room, or ambient temperature. These lamps are available with clear glass, or frosted bulbs, and reflectorized, in several shapes. In general, the light output based on physical size of the lamp is high. This permits higher lighting levels to be obtained with fewer luminaires of smaller size, and normally at lower first cost for the lighting equipment. Color quality of the light produced is yellowish, at lower wattages, ranging to yellowish-white in the higher wattages. The color of different wattages is different. Color correction, or use of the lamps as sources of colored light is accomplished by subtraction, or filtering out the unwanted colors with color filters. By virtue of their short burning life, they have to be replaced often, increasing maintenance and operating costs. But because of their simplicity, they can be replaced easily by anyone.

Mercury lamps have long life, average 6000 or more hours. They are approximately double the efficiency of incandescent lamps. They have an approximate point source for accurate light control, but they require an auxiliary transformer for operation. They are subject to a decrease in efficiency in abnormal ambient temperatures, and require a warming-up period in starting, and a cooling-off period when they are turned off, before they can be restarted. Their uncorrected color quality is a bluish-green white, but they are also available with a color-correcting fluorescent phosphor coating which greatly improves their color. The light output per lamp is high. This makes them highly suitable for lighting large areas per lamp, especially where accessibility to the lamp is difficult, as in street and highway lighting, floodlighting, and the lighting of medium and high bay areas in industrial plants. The color quality of the light produced, especially by the new color-corrected lamps, is also suitable for these areas.

Fluorescent lamps are line sources and are excellent for use where diffuse light distribution is indicated. They have long life, ranging up to 15,000 hours of op-

to err is human . . .

. . . but very costly

Replacing a blown fuse with one of the wrong rating is common . . . often the natural thing to do when the correctly rated fuse is not at hand.

This mistake, whether it is in error or an expedient means of putting the protected equipment back in service, is costly.

It accounts for poor product reputations and costly service expense to manufacturers.

There is no margin for error when your equipment incorporates HEINEMANN CIRCUIT BREAKERS. The correct rating is built right into your product. Once fault conditions have been corrected, service is restored instantly and easily with just a flick of the circuit breaker handle. No replacement necessary.

And, since HEINEMANN CIRCUIT BREAKERS serve as a power switch, too, overall costs of a circuit breaker and comparable fuse installation are quite close.

Send for your copy of the CIRCUIT BREAKER ENGINEERING Guide, just ask for Bulletin 201.

Heinemann General Purpose Three-Pole Circuit Breaker. Available in odd or fractional ratings from 0.010 to 70 amperes. (Other models to 100 amperes.) Ratings are not affected by ambient temperature.

HEINEMANN
ELECTRIC COMPANY
132 Plum Street, Trenton 2, N. J.

Circuit breakers

Rated Average Life of Fluorescent Lamps

Type Lamps	Burning Hours Per Start			
	3	6	12	Continuous*
Starter-Operated (15-, 20-, 25-, 30-, 32-, 40-, 90-, and 100-watt)	7500	Plus 25%	Plus 60%	Plus 250%
Rapid Start	7500			
All T-12 Slimline	7500			
T-6 and T-8 Slimline	6000			
Cold Cathode LP Cold Cathode HP	15000 25000	Life not affected by number of starts		

*Light output depreciates steadily as lamps are burned. Where infrequent starting or continuous burning is involved, lamps should be replaced before they reach average life for greatest lighting value.

Fluorescent Lamp Lumen Output Ratios

(Standard Cool White = 1.00)

Color of Lamp	Multiplying Factor
Deluxe Cool White	0.71
Deluxe Warm White	0.71
Daylight	0.93
Soft White	0.68
Green	1.20
Gold	0.60
Blue or Pink	0.45
Red	0.06

Data on Typical Fluorescent Lamps and Ballasts

Used for General Lighting

Number and Type of Lamps	Weight (lbs)	Line Current (amps)	Watts Consumed		Lumens per Lamp	Lumens per Watt**
			Ballast	Per Lamp*		
FOR 60 CYCLE, 110-125-VOLT CIRCUITS						
2 – 20	3.4	.42	9	24.5	1000	40.8
2 – 30	6.2	.70	18	39.0	1890	48.5
2 – 40	5.5	.85	16	48.0	2500	52.1
2 – 40T17IS	9.5	.95	30	55.0	2500	45.4
2 – 48T12	9.5	.95	30	53.0	2300	43.4
2 – 72T12	13.8	1.60	34	72.0	3600	50.0
2 – 96T12	13.8	1.60	34	91.0	5050	55.4
2 – 48T12RS	4.0	.85	12	46.0	2500	54.4
2 – 48T12RS/800	10.0	1.30	30	75.0	3100	41.4
2 – 72T12RS/800	14.0	1.70	30	100.0	4800	48.0
2 – 96T12RS/800	14.0	2.00	20	115.0	7250	63.0
2 – 90T17	10.0	1.00	21	100.5	5150	51.2
FOR 60 CYCLE, 220-250-VOLT CIRCUITS						
2 – 40	5.7	.45	18	49.0	2500	51.0
2 – 90T17	14.3	.93	31	105.5	5150	48.8
2 – 48T12RS	5.5	.43	13	46.5	2500	53.8
FOR 60 CYCLE, 240-280-VOLT CIRCUITS						
2 – 40	5.3	.37	18	49.0	2500	51.0
2 – 48T12	10.0	.43	28	52.0	2300	49.2
2 – 72T12	9.5	.74	30	70.0	3600	51.4
2 – 96T12	9.5	.74	30	89.0	5050	56.8
2 – 48T12RS	4.0	.39	12	46.0	2500	54.3
3 – 48T12RS	11.0	.55	18	46.0	2500	54.3
2 – 96T12RS/800	14.0	.88	20	115.0	7250	63.0
2 – 90T17	14.3	.83	31	105.5	5150	48.7
4 – 90T17	16.5	1.65	36	99.0	5150	52.0

*Includes lamp wattage plus watts loss in ballast.

**Overall efficiency, including ballast watts loss.

Lighting System Voltages

(Single Phase — Volts)

Incandescent Filament Lamps	Electric Discharge Lamps	High Frequency Systems
28-32	110-125	400*
110-125	199-216	600*
220-240	220-240	
	240-280	

*Phase-to-phase voltage, with grounded neutral to provide less than 300 volts to ground (NECode ruling).

eration in service, but averaging around 7500 hours based on normal practice of turning the lighting on and off which affects their life. Fluorescent lamps produce more light per watt than any other light source. Color quality can be controlled by the phosphors used, and produces colored light additively, or positively, which makes it ideal as a source for colored light. But in spite of the high efficiency of fluorescent lamps, their total light output per lamp is relatively low, thus requiring several lamps of relatively large size to produce a specific level of illumination. They require ballasts for operation, and are subject to reduction in efficiency in abnormal temperatures,

PUBLIC LIBRARY, ST. JOSEPH, MISSOURI

Irregular shaped ceilings often posed difficult lighting problems ...until GrateLite was invented. This is a louver that can be fitted to any shape!

results:

A new concept of ceiling design that distributes the light evenly throughout the room without glare and annoying shadows—an inviting, eye-soothing illumination of high intensity at low brightness.

MARTIN DELICATESSEN, UNIONTOWN, PA.

Beauty treatment for odd-shaped ceilings...

GUTH GRATELITE*
LOUVER-DIFFUSERS

* TM Reg. U.S. & Can. Pats. Pend.

LUTZ DRUG STORE, SAGINAW, MICHIGAN

Guth

THE EDWIN F. GUTH COMPANY
ST. LOUIS 3, MO.

trusted NAME IN LIGHTING
SINCE 1902

May we send you detailed information and layout guide FREE?

DODGE AGENCY GEN. OFFICE, SALINA, KAN.

lighting design purposes. However, number of lamp lumens per lamp. Lumen Method formula. The result

LAYOUT REMINDERS
For the Lighting System Designer

- *A customer buys a lighting system to provide an adequate, comfortable and appropriate lighting result* — not because he wants luminaires, lamps, conduit and wiring.
- *Luminaires and lighting equipment selected should be appropriate for the structure and the seeing problems involved.* Appearance, functional design, direct and reflected glare, shadows, maintenance, and lighting efficiency are all factors to be considered.
- *The lighting layout should fit the structural details of the building.* If plans and drawings are not available, survey the interior and note location of columns, beams, obstructions and other architectural features.
- *Use conventional layouts with symmetrical spacing of units, if possible, with luminaires parallel and perpendicular to walls.* Special geometrical patterns may be suitable in some cases but should be avoided generally unless they serve a specific functional or design purpose.
- *Use continuous-row fluorescent luminaires in preference to individual units.* The completed installation will look better and usually results in economies in wiring and installation.
- *Recessed and built-in lighting equipment does not light the ceiling.* Check your layout and room surface reflectances to see that use of such equipment will not produce uncomfortably dark ceilings nor excessive brightness ratios in the normal field of view.
- *Efficiency of trans-lighted ceilings is dependent to a great extent on the reflectance of the plenum cavity.* Be sure lamps can be mounted sufficiently high above diffusers or louvers to provide uniform brightness and spaced properly to provide desired intensity. Paint entire cavity white with highest possible reflectance.
- *Suspended luminaires of the direct-indirect type often produce the best lighting result most economically.* Check the suspension length carefully and limit it to the dimension which gives reasonably uniform ceiling brightness.
- *Luminaire spacings should be used which produce uniform illumination* and prevent undesirable shadows.
- *Consider the finish and reflection factor of ceiling and side walls.* Recommend proper colors and finishes to provide surrounding brightness conditions which promote eye comfort and good seeing conditions.
- *Plan the maintenance program along with the lighting layout.* Be sure that all luminaires and lighting equipment are easily accessible and are designed to be cleaned easily and quickly.
- *Double check all calculations and details* to insure the proper number of units and the ultimate desired lighting result.

either higher or lower than average. They also increase in efficiency when operated at higher frequencies.

In general practice, fluorescent lamps are being used for providing general illumination in most commercial applications and in low to medium bay industrial applications. Mercury lamps are used for medium to high bay applications in industry, for floodlighting, and for street lighting. Incandescent lamps remain more popular for home use, for direct lighting in stores, and for display and window lighting, for floodlighting of most sports areas, and for many special applications, especially where accurate light control is needed.

Lighting Calculations

The lighting designer needs a common basis for analysis of one lighting system versus another, particularly in view of the wide variety of materials and luminaire shapes, and the broad range of control methods available to him, and to keep lighting design on an accurate and scientific basis. Otherwise, it is contended that most installations of electric lighting provide far too little illumination of the quality desired, and that the limiting factor is economic rather than technological. Fortunately, the designer has such a basis for analysis in the several available methods for making lighting calculations. Because of their simplicity, the Lumen Method is recommended for estimating general lighting intensities, and the Point-by-Point Method for estimating supplementary lighting intensities. For commercial purposes these two methods are entirely adequate, and equipment manufacturers are supplying photometric data of the type needed for using these methods.

The design of general lighting systems is governed by room dimensions, structural features, reflection characteristics of walls and ceilings, mounting heights of the luminaires, and the distribution and maintenance characteristics of the luminaire. The choice of the luminaire depends on the service to which it is to be put. This assumes a certain experience in selection, or other aids, such as manufacturers' data. These assist the designer in making a selection appropriate from the standpoints of freedom from glare, efficiency, decorative value, and economy. The ultimate "brightness pattern" of the room is also an important factor in the design.

In designing general illumination for an area, the lighting designer first considers the provision of a specified average footcandle level of illumination to a horizontal plane (work plane at 30 in. above floor) in the area. This continues to be the only criterion for measuring the lighting result directly with a meter (which is unfortunate, as several other factors are equally important). The light generated by the lamps in such a system is variously affected and considerably reduced by reflection, diffusion, and absorption as it impinges on reflectors and transmitting media in the luminaires and on ceilings, walls, floors, and on objects in the room. The Lumen Method of lighting calculation, incorporating the Room Ratio method of general lighting design and Coefficient of Utilization data for a specific luminaire based on its type of light distribution, takes into account many of these variables in determining the average lighting level.

Presented here is a condensed Room Ratio table for quick reference, plus the Room Ratio formula for use when other dimensions obtain than those given in the table. Also given are coefficients of utilization for the five basic types of light distribution. These tables can be used to determine the CU value for use in the Lumen Method formula for lighting calculation, and in general will be found sufficiently accurate for most general

lighting design purposes. However, the practicing lighting designer should have on file complete CU tables for each luminaire he uses in his layouts, as supplied by the manufacturers for their own specific units, and these accurate CU values used where comparisons between systems are made. A conversion table is given (below) for converting Room Index values to Room Ratio values where manufacturers' tables still show Room Index listings of letters A to J.

Average "in service" footcandles of general illumination can be estimated for a room, by inserting appropriate values in the Lumen Method formula given in the Lighting Formulas Table (below, left). The procedure is as follows:

1. Determine the "total initial lamp lumens" by multiplying the number of lamp lumens per lamp by the number of lamps in the room.

2. Determine area of room in square feet.

3. Determine the Room Ratio for the dimensions of the room and the mounting height of the luminaires from the Room Ratios table, and then, using this Room Ratio value, determine the coefficient of utilization (CU value) for the luminaire being used, or for the basic type of light distribution of the luminaire in the "Coefficients of Utilization for Five Basic Lighting Systems" table.

4. Determine the maintenance factor (MF in the formula) for the type of luminaire being used. MF values are also shown in the CU table given here.

5. Apply these values in the Lumen Method formula. The result will be the calculated "average footcandles" maintained in service which may be expected after the luminaires have been installed and in use long enough for dust, lamp life and dirt to depreciate the initial light output to the value estimated for maintenance depreciation. By eliminating the MF value from the formula, the "initial average footcandles" will be indicated by the formula.

Large areas use light more efficiently than do small areas, as is indicated by the CU table for different Room Ratio values. This is because the ratio of wall area to floor area is less in larger rooms, and there is proportionately less surface to absorb the light.

Various methods for calculating illumination values for luminous

Lighting Calculations Methods

Type Lighting	Method of Calculation
General	Lumen Method Interflectance Method Zonal Lumen Method Point-by-Point Method
Supplementary	Point-by-Point Method Lumens-per-Foot Method
Floodlighting	Beam Lumens Method Point-by-Point Method
Street	Isocandle Curves

Formulas for General Lighting Design

To determine room characteristics in terms of room proportion (with respect to light utilization):

For oblong rooms —

(A) $\text{Room Ratio} = \dfrac{W \times L}{H\,(W + L)}$

For square rooms —

(B) $\text{Room Ratio} = \dfrac{W}{2h}$ in which:

W = Room width (feet)
L = Room length (feet)
H = Height from work-plane to light-center of luminaires, or to the ceiling.

To determine average illumination of the work-plane in footcandles (or lumens per sq ft) — Lumen Method:

(C) $Fc = \dfrac{\text{total initial LL} \times CU \times MF,}{A\ (\text{sq ft})}$ or

(D) Average lumens reaching work-plane $=$ total initial $LL \times CU \times MF$, in which:

LL = Lamp lumens
CU = Coefficient of utilization
MF = Maintenance factor

Room Index To Room Ratio Conversion

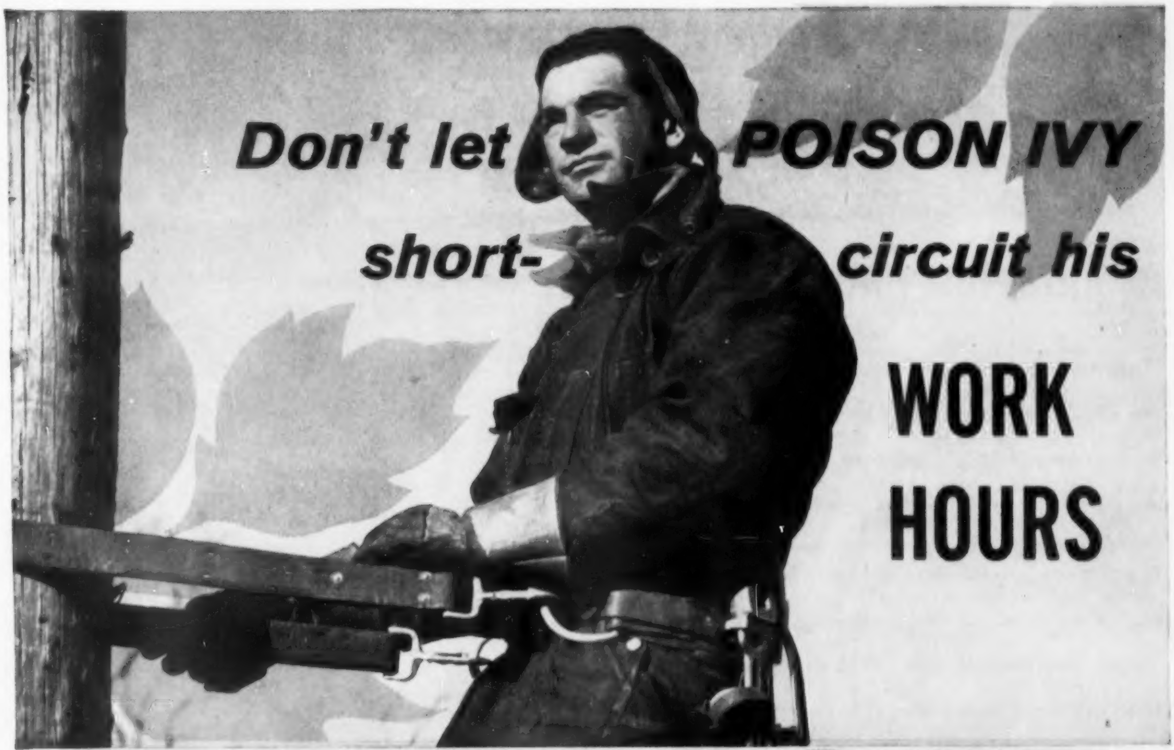
RI	A	B	C	D	E	F	G	H	I	J
RR	5.0	4.0	3.0	2.5	2.0	1.5	1.25	1.0	0.8	0.6

ROOM RATIOS

$$RR = \frac{W \times L}{H\,(W + L)}$$

ROOM W ft	ROOM L ft	Height of Luminaire above Floor* 8	10	12	15	19	27	43
10	10	0.9	0.7	0.5				
	14	1.1	0.8	0.6	0.5			
	18	1.2	0.9	0.7	0.5			
	24	1.3	0.9	0.7	0.6			
	30	1.4	1.0	0.8	0.6			
14	14	1.3	0.9	0.7	0.6			
	20	1.5	1.1	0.9	0.7	0.5		
	30	1.7	1.3	1.0	0.8	0.6		
	40	1.9	1.4	1.1	0.8	0.6		
	60	2.1	1.5	1.2	0.9	0.7	0.5	
18	20	1.7	1.3	1.0	0.8	0.6		
	30	2.0	1.5	1.2	0.9	0.7		
	40	2.3	1.6	1.3	1.0	0.8	0.5	
	60	2.5	1.8	1.4	1.1	0.8	0.6	
	80	2.7	2.0	1.5	1.2	0.9	0.6	
25	30	2.5	1.8	1.4	1.1	0.8	0.6	
	40	2.8	2.1	1.6	1.2	0.9	0.6	
	60	3.2	2.4	1.9	1.4	1.1	0.7	
	80	3.5	2.5	2.0	1.5	1.2	0.8	0.5
40	40	3.6	2.7	2.1	1.6	1.2	0.8	0.5
	60	4.4	3.2	2.5	1.9	1.5	1.0	0.6
	80	4.9	3.6	2.8	2.1	1.6	1.1	0.7
	100	5.2	3.8	3.0	2.3	1.7	1.2	0.7
60	60	5.5	4.0	3.2	2.4	1.8	1.2	0.8
	100		5.0	3.9	3.0	2.3	1.5	0.9
	140			4.4	3.4	2.6	1.7	1.0

*Work plane 30 in. above floor. Mounting height is floor to luminaire where downward component is 40% or more of light output. When light output is less than 40%, mounting height is floor to ceiling.



ZIRNOX®

can be relied on for effective

PREVENTION: Effectively wards off poison ivy, poison oak, poison sumac
— if applied before exposure
— or within eight hours *after* exposure

RELIEF: Eases itching and retards spread
— if applied in early stages

Contains hydrous zirconium oxide 4%, Bristamin dihydrogen citrate 1%, in a non-greasy lotion base.

Bristol
LABORATORIES INC
SYRACUSE, NEW YORK

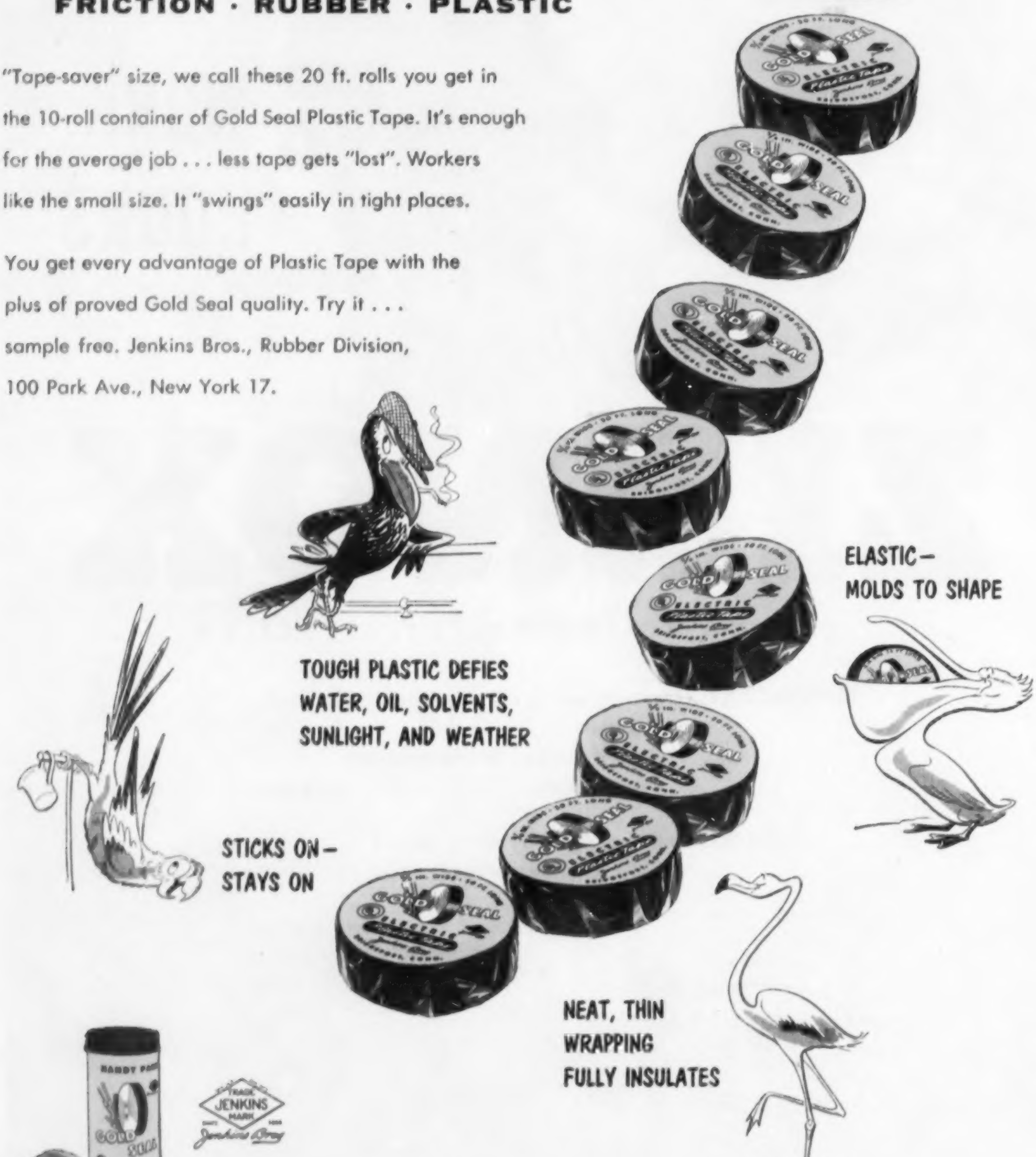
For top value . . . in any type . . . get JENKINS

Gold Seal Tape

FRICTION · RUBBER · PLASTIC

"Tape-saver" size, we call these 20 ft. rolls you get in the 10-roll container of Gold Seal Plastic Tape. It's enough for the average job . . . less tape gets "lost". Workers like the small size. It "swings" easily in tight places.

You get every advantage of Plastic Tape with the plus of proved Gold Seal quality. Try it . . . sample free. Jenkins Bros., Rubber Division, 100 Park Ave., New York 17.



TRADE JENKINS MARK

Gold Seal Plastic Tape — Handy Pack of ten 20 ft. rolls and single 60 ft. rolls in round metal cans.

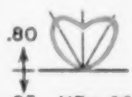
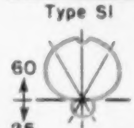
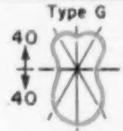
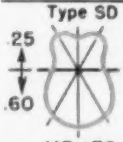
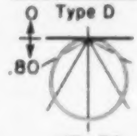
ceilings are currently in use. It is recommended that lighting designers follow the method recommended by each manufacturer for calculating the lighting levels for each manufacturer's own equipment until a universal formula is adopted. The CU values given in the accompanying "Coefficients of Utilization for Luminous Ceilings" table are measured values, under specified conditions for specific types of diffusers. These data may be used by making estimated allowances for variations from the specified conditions outlined for various installations.

An important consideration in the design of luminous ceilings or the use of large-area low-brightness self-contained units is the ambient temperature of the cavity in which fluorescent lamps are used. The light output of fluorescent lamps decreases as the ambient temperature increases from a normal of 60 to 80 degrees F, as is the case in non-ventilated enclosures, and decreases as the temperature decreases below this normal. Fortunately the most efficient operating range for the lamps is in the range which exists on average jobs which are air-conditioned.

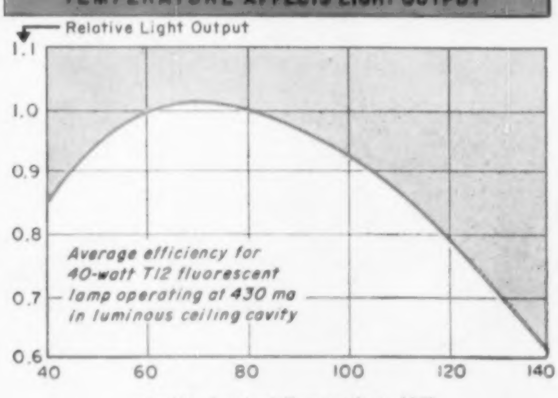
Luminaires used for general lighting purposes should provide a high overall efficiency. They should also be designed to provide the necessary comfort in vision. The light sources should be shielded to prevent direct glare in the normal field of vision and should also prevent or minimize reflected glare. This is especially important for lighting systems selected for offices, drafting rooms, classrooms, and areas where visual tasks are difficult and maintain over long periods of time.

Depending on the area to be lighted, it is often necessary to first select the type of luminaire which is to be used, and then plan the equipment layout around the light distribution of the luminaires selected. This procedure has the advantage of making it possible to use a lighting system with specific desirable characteristics, and to adapt the layout to meet the necessary conditions imposed by the size

Coefficients of Utilization for Five Basic Lighting Systems

Typical Light Distribution	Ceiling	80%		50%		80%	
	Walls	50%	30%	10%	10%	50%	30%
	Floor	10%		10%		30%	
Type I	RR						
	0.6	.27	.21	.17	.11	.28	.22
.80	1.0	.39	.33	.26	.18	.42	.35
	2.0	.55	.49	.36	.29	.60	.52
	3.0	.61	.56	.40	.34	.69	.62
.05 MF = .60	5.0	.68	.64	.44	.39	.78	.72
Type SI 	0.6	.24	.19	.17	.11	.24	.19
60	1.0	.35	.30	.26	.19	.37	.31
	2.0	.49	.44	.36	.29	.53	.47
	3.0	.55	.50	.40	.34	.61	.55
25 MF = .65	5.0	.60	.57	.45	.39	.68	.63
Type G 	0.6	.26	.21	.23	.16	.27	.22
40	1.0	.38	.33	.33	.26	.40	.34
	2.0	.53	.48	.44	.38	.57	.51
40	3.0	.59	.55	.49	.44	.65	.59
MF = .70	5.0	.64	.61	.54	.49	.73	.68
Type SD 	0.6	.34	.28	.31	.24	.35	.29
.25	1.0	.48	.42	.44	.36	.50	.43
	2.0	.64	.59	.58	.51	.69	.62
.60	3.0	.70	.66	.63	.57	.78	.72
MF = .70	5.0	.75	.72	.68	.63	.86	.81
O Type D 	0.6	.34	.28	.33	.24	.35	.28
.80	1.0	.49	.42	.47	.37	.51	.43
	2.0	.65	.60	.63	.55	.71	.64
	3.0	.72	.67	.69	.63	.80	.74
MF = .70	5.0	.78	.75	.75	.71	.89	.85

TEMPERATURE AFFECTS LIGHT OUTPUT



Coefficients of Utilization for Luminous Ceilings

Diffuser[1]		Corrugated Acrylic Plastic[2]			Corrugated Vinyl Plastic[3]		
Walls		50%	30%	50%	50%	30%	50%
Floor		10%		30%	10%		30%
Room Ratio	5.0	.64	.60	.71	.59	.55	.60
	3.0	.58	.54	.64	.54	.49	.54
	2.0	.51	.47	.58	.48	.43	.47
	1.5	.46	.42	.52	.42	.38	.40
	1.0	.38	.34	.42	.33	.29	.30
	0.6	.27	.22	.28	.23	.19	.20

1—Based on wall-to-wall diffusing panels.
2—Cavity efficiency of 68%; Diffuser transmittance of 53%; Diffuser reflectance of 39%.
3—Cavity efficiency of 62%; Diffuser transmittance of 45%; Diffuser reflectance of 45%.

and light distribution characteristics of the luminaires or lighting equipment selected. But if the appearance of the physical layout of luminaires is of major importance, the equipment layout should be made first, and luminaires or lighting equipment then selected to meet these artistic requirements.

While it is important to provide specific levels of illumination, there are also other factors which are of equal importance. One such factor is the matter of brightness and brightness contrast. The brightness of luminaires, or of lighted elements including luminous ceilings, should be kept at a minimum. Areas of brightness should be surrounded by areas whose brightness contrast is not great, as such conditions constitute glare. Care should be taken when luminaires or equipment are recessed flush in the ceiling, to insure that the contrast between the ceiling and the recessed units is within comfort limits. When recessed equipment is used, ceiling should be finished white or in very light colors. Light walls, floors and furniture are also desirable on recessed installations, as these will usually reflect enough light back to the ceiling to prevent undue contrast. Manufacturers of lighting equipment now supply Visual Comfort Index data for most of their equipment which enables the lighting designer to predetermine lighting comfort.

Supplementary Lighting

Current practice is to provide general lighting in stores, offices, classrooms, production areas, and for similar purposes, in illumination intensities ranging up to 100 footcandles and above, depending on the degree of severity of the seeing tasks involved. But for many applications, such as for inspection, fine machining, color work, etc. in industry, for display lighting in stores, and similar critical seeing tasks, it is desirable and more economical to provide higher lighting levels ranging up to 400 and 500 footcandles over small work areas with supplementary type lighting. Usually this is done with reflector type units installed close to the areas, or with reflector spot or flood lamps in suitable fixed or adjustable type holders. Both incandescent and fluorescent units are used for this purpose.

The point-by-point method of calculations is used to determine estimated intensities from individual supplementary type units. It is necessary, of course, to have a candlepower distribution curve for the unit being considered. The intensity may then be calculated for a point at any angle from the center axis of the unit, or on the axis, using the formulas shown in the illustration below. Most manufacturers of such equipment also supply charts showing footcandle values over a specified area located a given distance from the unit, which eliminates the need for time-consuming calculations.

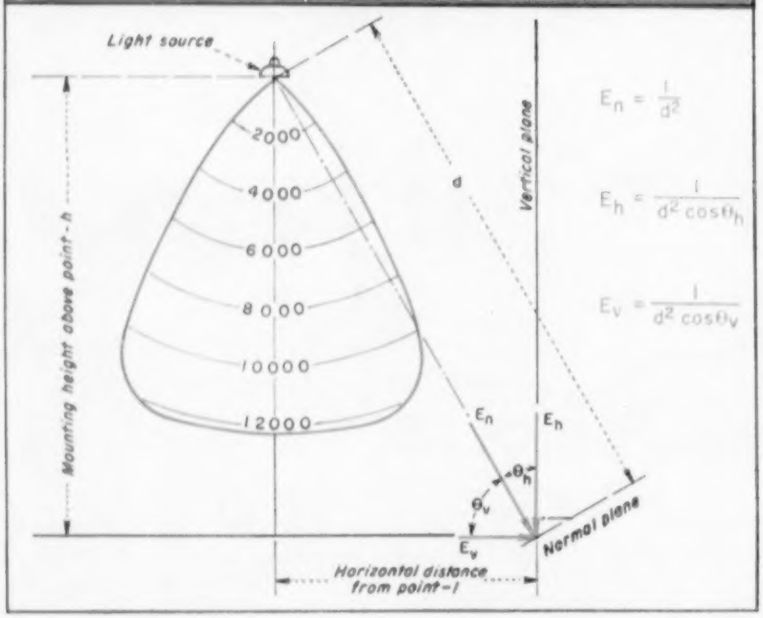
Color in Lighting

Color is one of the most important considerations in lighting design. Yet, it is usually one of the most neglected. To the layman, a relationship between color and lighting seems pretty far-fetched. And even to the professional illuminating engineer, it is difficult for him to grasp and fully understand the full impact of color as it affects the final lighting result. Similarly the subject is too broad, and too complicated, to cover in any detail here. All that is intended is to point out very briefly some of the fundamental principles which are involved in color problems faced by the lighting designer on every lighting system design, so that he will be more alert to these problems. Literally thousands of books and articles have been written on the subject of color, but far too few relate to color in light and lighting.

Light is radiant energy which constitutes the visible spectrum. It is composed of pure spectral colors, or so-called color regions. In their simplest form, these color regions are divided into nine well-known parts: violet, blue, blue-green, green, yellow-green, yellow, orange, light red and dark red. When combined in appropriate quantities of radiant energy these "colors" produce "white" light. So the lighting designer is working with "color", fundamentally, when he works with light.

Each type of light source produces a different color quality of light. That is to say, each type of light source produces radiant energy of different wavelengths, which the eye perceives as a color sensation depending on how the radiant energy is distributed over

POINT-BY-POINT CALCULATIONS



Fits Smallest Single-gang Box without

the visible spectrum. Even the color quality of daylight is not constant; it varies throughout the day and by geographical direction. Incandescent, or filament lamps, produce a yellowish white light. Mercury vapor lamps (without color correction) produce a greenish white light. And fluorescent lamps are purposely made in a variety of "white" colors for general lighting applications. It is the lighting designer's responsibility to select the proper light source from these available lamps to provide the correct "color" of white light for each lighting application for which he is responsible.

Every object on which light falls also has color. By definition, the color of an object is "the capacity of the object to modify the color of the light incident upon it". Thus there is an interdependence of light and color which the lighting designer cannot ignore. First, he must know the color (and reflectance values) of the various surfaces in the interior which he plans to light in order to select an appropriate "color" of light source, or conversely he must work closely with the architect, interior decorator, or owner to select appropriate colors for all interior surfaces (ceiling, side walls, floor, furnishings) which will work harmoniously with the "color" of the light sources to be used.

Color also creates an effect of psychological significance. It can be used effectively to provide a psychological "warmth", or "coolness", or mood of "action", or of "somberness", etc. So here, too, the lighting designer can provide suitable lighting to complement the decorator's color treatments and thereby produce a more effective decorative "mood", or theme.

Colored light, or light having its radiant energy concentrated in specific regions of the color spectrum, may also be used as such to create unusual and decorative effects. The primary colors of light are red, green and blue. By mixing these primary colors of light in proper proportions, white light is produced. By using various combinations and intensities, an almost unlimited range of "color" effects are possible. Applications for this type of lighting are practically endless, and designers should know and understand this field well to design better and more elaborate systems which reflect color harmony.

Residential Lighting

Lighting for the home should tie in with family life and activities. Family size, living habits, social activities, sports, hobbies, and similar factors vary greatly. Therefore, wherever practical, home lighting should be custom-designed to meet the specific requirements and individual preferences of the individual family.

Fundamental to home lighting design is the provision for a wide variety of lighting effects, to enable the proper environment to be created for each family activity, seeing problem, or decorative treatment. This demands the use of many different lighting techniques and types of lighting devices, with maximum control flexibility. Only through this approach to the home lighting problem can the family begin to approach the many benefits and conveniences of better light for better living.

The principal purpose for lighting in the home is to provide comfortable seeing for work, play and relaxation. But it can, and should, be made to serve many other needs. It should enhance the appearance, the atmosphere and the decorative treatment that helps to transform a house into a home. It should create a sunny and cheerful mood and environment. It should be flexible to permit a wide variation in lighting effects to meet varying moods, and for psychological and decorative value.

Lighting Load Affects Air Conditioning

1. **Heat from a lighting load is measured in —**

   Btu's per hour

2. **A lighting system produces a Btu per hour heating load equal to —**

   Lighting Kilowatts* x 3414

3. **Required tons of air conditioning to remove a lighting system heat load is equal to —**

   $$\frac{\text{Btu's per hour (from 2)}}{12000}$$

4. **One ton of air conditioning capacity will remove the heat for a lighting load of —**

   3500 watts

***Add both lamp wattage and ballast watts loss for fluorescent lighting systems.**

The lighting environment in the home, as in commercial establishments, extends beyond and is influenced by more than just the lighting system. It includes the walls, ceilings, floors and furnishings. These areas reflect light and cause rooms to appear larger, more cheerful, more colorful, more livable, when medium to light finishes are used. Dark finishes have the opposite effect.

The broad range of light sources, lighting techniques and lighting units makes it possible to select lighting systems which fit family budgets, yet remain appropriate for varying decorative treatments for individual family habits and requirements. When combined with appropriately finished light colors on all interior surfaces, a more satisfactory lighting environment may be expected.

From a lighting design standpoint, the rooms of a house can be divided into two basic groups. For one group, consisting of living room, dining room, bedrooms, den or study, halls and stairway, and recreation or play room, general diffuse illumination should be provided throughout each room, supplemented by local lighting at all furniture groupings or local areas where higher intensities may be needed for difficult seeing problems. Also, provision should be made to use light in these rooms as a decorative medium. For the other group of rooms, consisting of kitchen, bath, laundry, pantry, etc., or service areas, a higher level of general lighting for utilitarian purposes should be planned.

For general illumination, overhead ceiling lights are generally most satisfactory. In the living room, dining room and bedrooms, these should be decorative in character to harmonize with the furnishings, or may consist of coves, valances and cornices where the budget will permit. Recessed spots and floods, carefully shielded, may also be used to light murals, pictures, indoor plants or flower arrangements, etc. Lighted ornaments, wall cabinets, etc. may be used as purely decorative devices.

In the kitchen, uniform general illumination may be provided by a

ceiling lighting system, ranging from a single ceiling unit to a complete wall-to-wall luminous ceiling. Large-area low-brightness recessed panels are an excellent intermediary solution. Supplementary lighting should also be provided over all work areas—food preparation, range, dishwashing center. Recessed incandescent units with concentrated light distribution can be used for some of these areas, and fluorescent wall brackets, or fluorescent strip lighting under cabinets, are also suitable where they can be installed.

In the bathroom both an overhead ceiling luminaire and two wall brackets, one on either side of the mirror, are desirable.

Overhead utilitarian lighting units are desirable in the laundry, in the furnace room, over a work bench, in the garage, and in other similar service areas.

The general principles of good lighting design should be followed in lighting each area of the home. Less emphasis is required on footcandle intensities, except for sewing and study areas, and for locations for relaxed reading, and greater emphasis is desirable on the decorative aspects.

Portable floor and table lamps incorporating good lighting design principles may, of course, be used. But these present the hazard of portable cords, and take up needed floor space. In general, equal or improved lighting effects can be provided by suitable built-in or permanently-installed standard lighting units. When these fixed units are properly controlled by switches or dimmers, full flexibility results and the system is much more satisfactory.

There is such a wide variety of units and equipments available as to make it impracticable to attempt a more detailed procedure for designing the lighting for a home in the limited space available here. It is believed that the general principles of home lighting design outlined above, if followed, will serve as a suitable guide, when implemented by the experiences and inherent creative ability of the average lighting designer.

Outdoor Lighting

Every home needs a certain amount of outdoor lighting for utilitarian purposes. In addition, many homes present an opportunity for the lighting of yards, lawns and grounds for increased use and beauty, and for artistic effects after sundown.

Lighting for utility includes the installation of lighting units at strategic locations for the quick and easy seeing of both visitors and members of the family on entering or leaving the house, garage, or grounds, and to discourage trespassing. This includes an illuminated house number (at driveway entrance, on the lawn, or at the front door), wall brackets, step lights, eaves-recessed or surface mounted floodlights, at the front entrance, post-top lanterns at the end of the entrance walk and at the driveway entrance, bracket light or floodlights for the rear entrance to the house and over the garage door, and floodlights or low-mounted lights to light walks and driveways.

Outdoor lighting may also be used for lighting entertainment and play areas, such as tennis courts, outdoor volley and basketball courts, barbecue pits, shuffleboard courts, ping pong tables, croquet courts and private swimming pools. The extent to which this type of outdoor home lighting is practical will be governed, of course, by the existing facilities of this type and the habits and outdoor activities of the family.

Lighting units installed for utility, or to provide safety for entry and exits to the house and garage, may also be used on a special lighting circuit to provide lighting for protection. Also, special floodlights or prismatic lens units may be mounted around the perimeter of the house, and connected to a special circuit specifically for protective lighting.

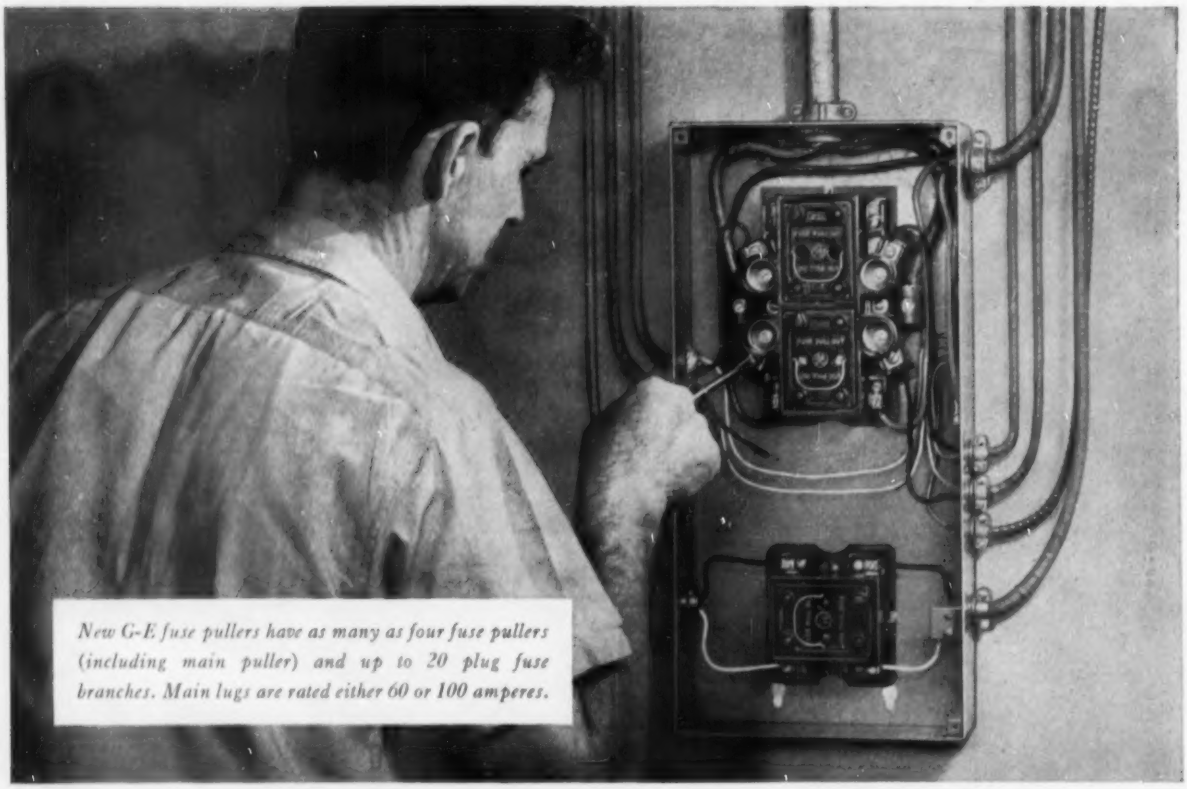
With more and more families being attracted to outdoor living during summer months, and year-round where climate permits, outdoor lighting for decoration can be used to excellent advantage. Vistas out the living room windows, or from the terrace, can be made most pleasing at night through the intelligent use of light and color. Artistic patterns of light and shadow can be created, and by means of multiple switching arrangements and dimmer control, the total lighting pattern may be adjusted to changing mood and artistic fancy.

A wide variety of types of outdoor lighting units are now available for lighting flower beds, or shrubbery, for underwater lighting in color of swimming pool or reflection pool, for fountains, lily ponds, rock gardens, and similar points of interest. Brightness patterns may be created outside large glass windows to provide a natural transition between outdoor and indoor areas. Overhead strings of lights, enclosed in Japanese lanterns or similar decorative devices can be used to add gaiety and a festive mood for outdoor parties. Lighting designers can devise individual and artistic applications to suit specific outdoor areas of individual home owners.

Major Causes of Light Loss in Lighting Systems

Cause of Depreciation	Percent Loss
Lamp Depreciation (End of rated life)	
Incandescent	20
Fluorescent	30
Mercury Vapor	23
Circuit Voltage Depreciation	
With adequate wiring	Negligible
With poor wiring and overloading of circuits	5-20
Luminaire Light Absorption	18-35
Paint Depreciation	5
Absorption of light by walls, ceilings, floors and other surfaces	(per year)
Dirt and Dust Depreciation	
1-month cleaning intervals	10
3-month cleaning intervals	15
6-month cleaning intervals	20
Cleaned when lamps burn out	30
Lamp Outage Depreciation	Up to 12


Silent
Partner
ADVANCE
BANK



New G-E fuse pullers have as many as four fuse pullers (including main puller) and up to 20 plug fuse branches. Main lugs are rated either 60 or 100 amperes.

Straight-in wiring and slide-out interiors in new G-E fuse pullers simplify job from start to finish

7 fusible devices offer 7 quality extras at no extra cost

1. **Straight-in wiring** for quick connections. No looping wires around screws, just insert and tighten. Grips like a bear trap.

2. **Exclusive slide-out interior** gives plenty of working room. No screws to fumble with or lose. Interior slides in and out with perfect alignment.

3. **Narrow, shallow box** construction makes it easier to mount box flush with wall. A G-E exclusive.

4. **Plenty of easily removed knockouts** make it simple to bring cable into box at most convenient place.

5. **Current-carrying parts are silver-plated** for cool operation, won't waste electricity. A G-E exclusive.

6. **Snap-action fuse puller** prevents partial contact Exclusive construction helps prevent overheating, nuisance fuse failure and call backs.

7. **Bonderite* finish** resists corrosion; protects against rust. Another G-E exclusive.

New G-E fuse pullers have 60 or 100 amp. main lugs. Seven basic designs include series or parallel wiring and sealable pullers for separately metered equipment. U/L listed. Surface or flush mounted designs. Ready for quick delivery from your G-E Trumbull Distributor.

*Parker Rust Proof Co.

GENERAL ELECTRIC

Signals and Communication

THE information given in this section covers a wide range of signal and communication systems. The material has been laid out according to types of buildings, presenting selection and application data on the types of systems used in each type of building. For each type of building, discussion of the different systems includes all important considerations which an electrical designer must make to incorporate signals, alarms and communication systems in the overall electrical design. As a result, this presentation represents a comprehensive check list of such systems with their operating principles and advantages.

For any particular application of signal and/or communication systems, design details are closely related to the types of systems and manufacturers' instructions. The many manufacturers of such equipment make available much literature and offer engineering services to assist the electrical designer.

The National Electrical Code covers signal and communication systems in Articles 640, 725, 800 and 810.

Industrial Systems

Industrial plants require a variety of signaling and communication systems, some having individual control equipment, and others interconnected or combined at one point to be supervised by the plant superintendent or the guard personnel. The usual method followed in combining the systems is to terminate the wiring in the respective control equipment cabinets and extend the supervisory equipment such as pilot lights, trouble bells, meters, etc., to panels in a console type of desk. This would include the fire alarm, watchman's tour, program cross-connection, door alarm, sprinkler alarm, burglar and hold-up alarms, smoke detection systems and transformer supervisory systems.

Besides the systems indicated above, other systems used are: intercommunicating telephones; paging systems; public address sound systems; clock and program bells; conveyor alarms; dispatching, loading and stockroom systems; liquid level, pressure, flow and temperature indicator systems; valve and electric current control systems.

Fire alarm systems should be of the closed-circuit supervised type. City and State ordinances should be checked regarding requirements. Generally non-coded systems are limited to small plants, since they only transmit a general alarm and do not indicate the location of the operated station. Coded systems are preferable since each station transmits a distinguishable signal. Plain code systems are generally acceptable for a single building. Group systems, using coded stations, are preferable where several buildings are involved. In this type of system, when a station is operated in one building, the signal devices in that building sound and in addition certain predetermined bells sound at specified supervisory locations such as in the power house, executive offices, etc. Stations must be located near stairways and other paths of escape and must be spaced so that no one need walk more than 100 ft to one. Audible signals such as bells, usually 10 in. in diameter, or horns of the grille or projector type are distributed throughout the areas so that they may be heard by all persons. An audible signal such as a small bell should be located in the guard room together with a punch recorder and take-up reel and a time stamp for a permanent record of each alarm. The maximum number of bells or chimes which may be connected on a circuit operating on alternating current is ten. For horns the maximum is also ten, however, certain types are electrically limited to nine. In addition to above mentioned systems, a type may be provided with approved features for the connection of an interior fire alarm to a municipal system.

Automatic fire detection systems may be used separately or combined with the manual fire alarm systems. They should be used in large or small areas such as storerooms, warehouses, boiler rooms and in ducts. Those mounted in ducts may be arranged to disconnect motor-driven blowers and to close dampers in sections of the ducts to prevent further spread of the hazard. When combined with manual fire alarm systems of the coded type, the automatic systems may be interconnected by using electrically tripped

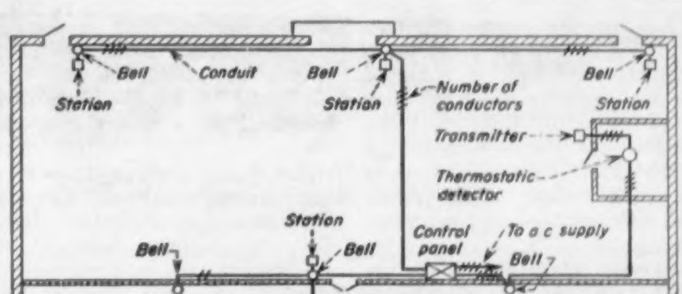


FIG. 1-LAYOUT OF FIRE ALARM SYSTEM

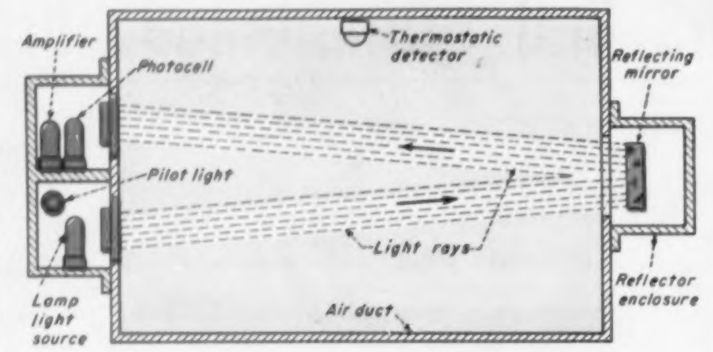


FIG. 2—PHOTO-ELECTRIC SMOKE DETECTOR INSTALLED IN AIR DUCT

transmitters. In this way a separate and distinguishable signal may be given for these protected areas. Combination fixed temperature and rate-of-rise thermal detectors usually protect an area of 900 sq ft. Those of fixed temperature only can protect from 225 to 400 sq ft depending upon the type. A typical layout of a fire alarm system is shown in Fig. 1.

Watchman's supervisory systems should be of a type which will require the watchmen on the various tours to produce a record in the superintendent's or chief guard's quarters at the start and at the finish of each tour. It should also contain provisions for the calls to be made to each station and in sequence. If so desired, extra features may be included, such as a delinquency indicator which will signal the chief guard when a watchman is delayed in arriving on time at a station. Or a telephone jack and a pilot lamp at each station may be provided so that communication may be had between headquarters and the outlying points. The telephone jack is used for plugging in a handphone which is equipped with cord and plug, while the lamp is used to notify the watchman along the tour that he is to call the central point. All tour stations must be located at remote points to insure complete coverage of the premises.

Sprinkler alarm systems are used to signal when sprinkler heads open, when noticeable leaks occur, when waterflow valves operate in either dry or wet systems, when post indicator valves operate or are left open or when the shut-off valves are placed in a sub-normal position. All of these valves are equipped with contacts so that an alarm will be transmitted to either audible signals, annunciators or a combination of same. A supervisory control panel or an annunciator should be provided to indicate the condition of each circuit. A coded signal may be transmitted to the signal devices of a coded fire alarm system by interconnecting the sprinkler system wiring through an electrically tripped transmitter. These transmitters should be connected to separate supervised circuits on the fire alarm control panel.

Smoke detection systems are used to detect smoke in ventilating, air-conditioning and dust-collecting ducts. It may also provide for disconnecting the air blower motor, and to close dampers in various sections of the duct system to prevent spreading of smoke and fire from one point to another. This is accomplished by means of photo-electric systems wherein the light source directs a beam to a photo-electric cell across the interior of the ducts. The photo-electric equipment may be adjusted to operate when the smoke in the ducts reaches a predetermined density. The control equipment transmits the signal to annunciators together with an audible alarm at the guard's quarters, and may also be interconnected with the manual fire alarm system. Thermostatic detectors may be installed in the ducts to indicate abnormal rise in temperature. A typical photo-electric duct installation is shown in Fig. 2.

Burglar alarm systems may be used to protect all doors, windows, elevator openings, skylights, etc., which may be readily accessible by a possible intruder. This is accomplished by the use of various types of spring contacts, switches, foil tape and networks of wired latticework. Photo-electric equipment may be used to protect stockrooms, toolrooms, filerooms and loading platforms. Safes and cabinets may be protected by special electrified enclosures or capacity alarms. All signals should terminate in a control cabinet at the chief guard's quarters.

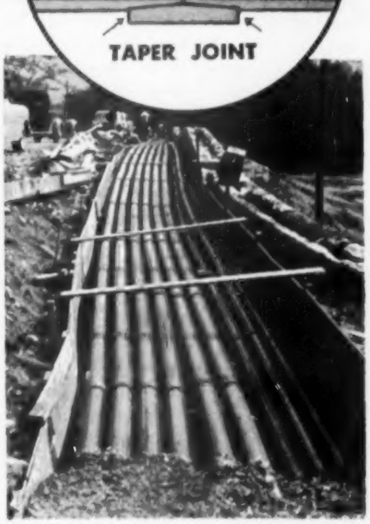
Door alarms are used to signal the guard room when certain restricted areas have been entered or vacated by individuals. The doors are provided with contacts which operate lamps or drops in annunciators. These systems are generally of the closed-circuit type using relays to supervise the equipment and the wiring. An audible signal such as a bell or buzzer is provided at the supervisory location with isolating switches for each circuit. In addition it is desirable to operate a large alarm bell adjacent to each guarded door.

Hold-up alarms may be used in the disbursing office using special pushbuttons, foot and knee contactors at desks and counters. Signals should terminate in a control cabinet at the chief guard's quarters with extension signals, either audible or silent (lamps) to possible points of apprehension.

Transformer supervisory alarm systems may be used to designate a dangerous increase in the temperature and pressure in oil-cooled transformers. Temperature and pressure switches are provided for this purpose and are inserted into the transformers. These switches are connected to supervisory contol cabinets located in the engineer's office or the guard room. Provision may also be made for the release of CO_2 tanks in the transformer vaults.

Paging systems are used to call and locate individuals for answering telephones, attending meetings, etc. In general these systems may be either of the coded, sound or visual type. The coded type consists of a code transmitter with audible signals such as bells, horns, chimes or mild-toned sounders and the associated control equipment. The

SMOOTH BORE!



Orangeburg Fibre Conduit Prolongs Cable Life

Protect cable sheath from abrasion and you prolong the life of underground cables, say utility engineers. Scoring of cable sheath creates "trouble spots" that shorten cable life.

That's where Orangeburg Fibre Conduit plays an important part in keeping cables healthy. Orangeburg's smooth bore, its low coefficient of friction minimize the danger of abrasion when cables are pulled in, as well as later on during cable movement. By protecting cable sheath from abrasion, Orangeburg Fibre Conduit adds years to cable life.

Orangeburg's impermeable wall and watertight joints protect cables from corrosive ground waters. Its nonmetallic material is strong, tough, resilient, long lasting.

And, remember, Orangeburg lays faster and at lower cost than other types of conduit. It is light in weight, easy to handle, easy to tool on the job. Spacers, bends, fittings, 5° bend sections and lightweight tapering tool, all combine to simplify installation.

Since 1893, records of long life have proved Orangeburg's durability and economy.

Orangeburg Fibre Conduit is distributed by Graybar Electric Company and General Electric Supply Company with branches and stocks in principal cities.

WRITE DEPT. ECM-56 FOR NEW CATALOG 52.

ORANGEBURG MANUFACTURING CO., INC., Orangeburg, N. Y. West Coast Plant, Newark, Calif.

ORANGEBURG®
FIBRE CONDUIT

sound system consists of a microphone(s), a number of loudspeakers and the associated amplifier equipment. The visual system used in laboratories and offices consists of a keyboard, lamp annunciators and the necessary control equipment for flashing the lamps and operating a selective buzzer signal when desired. Code signals are assigned to the personnel in the coded system. Code numbers are assigned in the visual type of system.

Clock and program systems are used for indicating the time of day and operating signal devices such as bells or horns at pre-determined times such as starting and stopping work, rest periods, lunch periods, etc. In addition they may also include time stamps, employee's time recorders, elapsed time or job recorders, etc. These systems may be provided with synchronous-motored movements or minute-impulse movements. Provision may also be made for a test signal on the fire alarm system.

Intercommunicating telephone systems may be provided in various forms, and the selection should be based upon the practical requirements. There are cases in small plants where a 2-station or pair of telephones are desired to converse between two points. For larger installations up to about ten stations, where only one conversation is found necessary at one time, the common-talking selective ringing system may be used. In systems requiring a greater number of stations the selective-talking selective-ringing type should be used. Where it is desired to have a small number of telephones supervised from one location, and only one pair of conversations are desired at one time, a master common-talking system is frequently found satisfactory. For large systems the manual switchboard or the automatic dial type systems should be used.

Public address sound systems may be used throughout the plant for paging, radio programs, recordings, announcements and entertainment derived from a centralized system. Loudspeakers of the proper type and size are distributed throughout the premises with the wiring terminating at the control center.

Conveyor signal systems are used to indicate to various locations that conveyors are to operate, when they are to stop and when an emergency exists. The system usually consists of pushbuttons which are connected to operate bells or horns. In addition photo-electric units may be installed at various points along the conveyor route with counters to designate the passing of different articles along the line.

Dispatching, loading and stockroom systems are used for checking materials and shipments, giving instructions, releasing trucks, etc. The equipment may consist of telephones, annunciators, sound communication units and microphones with loudspeakers with talk-back features. This equipment is generally used between two or more points between the office of the shipping room, loading platform or stockroom.

There are many systems which may be used in manufacturing processes. Liquid level indicators supervise the high and the low levels of liquid contents in tanks, cisterns, reservoirs. Pressure indicators supervise all measurable forms of pressure such as air, oil, water and steam. Temperature indicator systems supervise liquid and area temperatures. Control valve systems supervise all types of devices. They transmit signals to show that a change has occurred from a normal position or condition to a sub-normal one or the reverse. Electric current control systems supervise the electric power. They indicate when the current is interrupted and when it is restored. A record of these activities may be made on an annunciator.

Commercial Building Systems

Modern office and commercial buildings, whether located in large or small cities are faced with similar basic problems insofar as protection and expediency is concerned. The chief difference between industrial and commercial systems is in the extensiveness of the requirements. The contents and the records in many commercial buildings are considered very valuable and in many cases are not replaceable, and therefore, warrant the best and complete protection. And thorough study must be given to the matter of possible fire hazards and methods of detecting a fire at the incipient stage where time is of great importance.

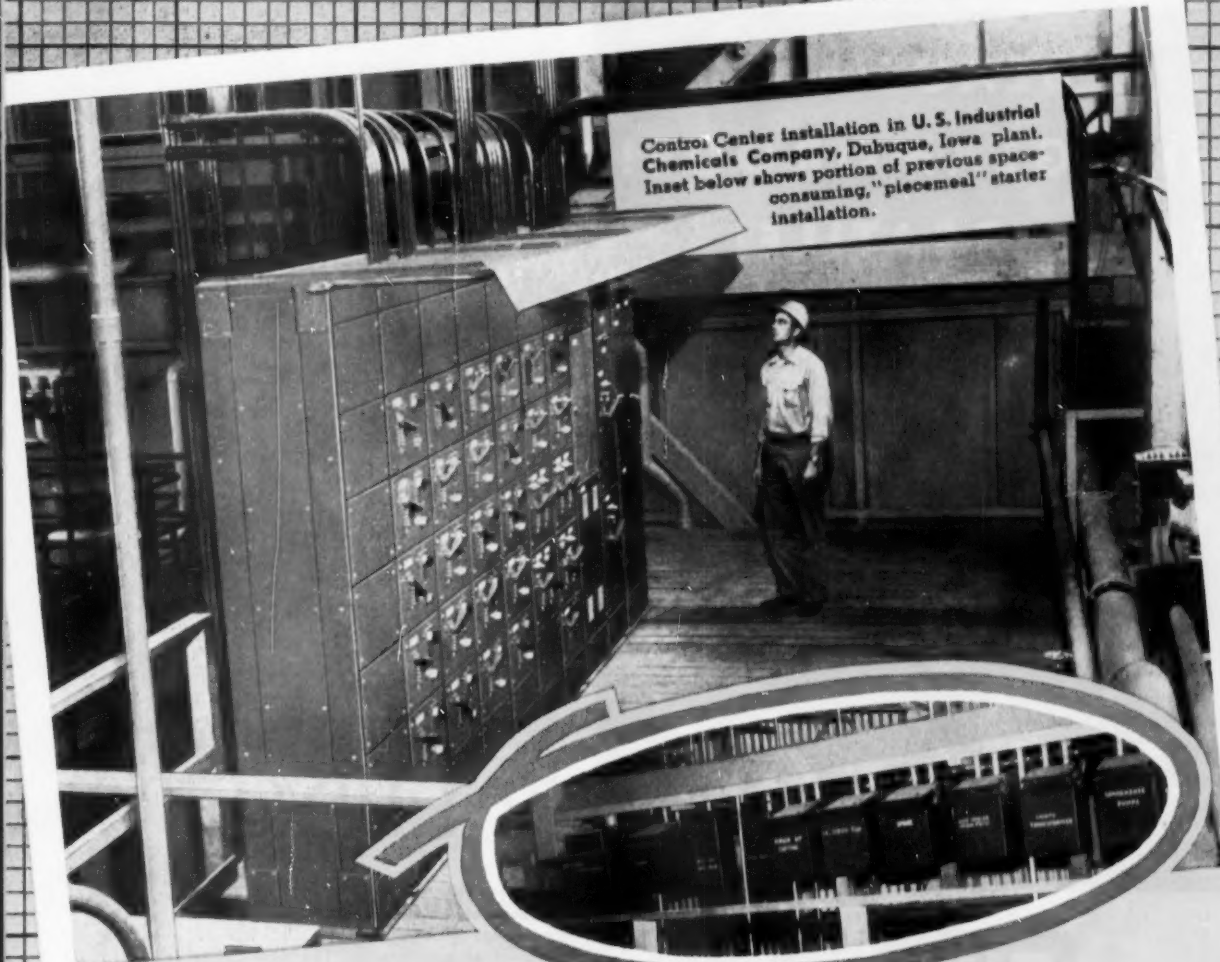
The types of systems used in office and commercial buildings are fire alarms of the manual and the automatic types, fire-line signal and telephone systems, watchman's tour, sprinkler alarm, smoke detection systems, protective alarms, call systems, clock and program systems, garage ramp systems, intercommunicating systems, elevator signals and door signals.

Fire alarm systems of the manual type should be installed for the protection of the general public and the employees within the building. Such systems may be of the same type as outlined for industrial buildings.

Fire alarm systems of the automatic type should be installed at all points where records or files are kept or stored. These systems are composed of a quantity of equally distributed thermostatic detectors grouped into zones and wired to annunciator control boards, or combined with the manual fire alarm system through electrically tripped transmitters. These transmitters, annunciator control boards or detectors may be connected to any signal such as bells, horns and the like, as separate systems if desired.

Fire-line signal systems are similar to standard coded fire alarms of the closed-circuit type with the addition of manually operated signal stations which are installed on alternate floors of tall buildings. These manual stations have hinged doors, are equipped with special cylinder locks, and are composed of closed-circuit strap keys which are used exclusively by members of the fire department to transmit signals to the pump room. The coded and the manual stations are all connected in series. The bells are of the single stroke type and are located in the pump room, elevator shafts and at all points required by the local fire prevention authorities. This feature may also be added to pre-signal fire alarm systems in which case the initial operation of the pre-signal station transmits the coded signals on the fire line or pilot bells. The second operation of the pull lever in conjunction with the insertion of a special plug or key in the station will operate the general alarm on all bells in the system.

Fire-line telephone systems are



Control Center installation in U. S. Industrial Chemicals Company, Dubuque, Iowa plant. Inset below shows portion of previous space-consuming, "piecemeal" starter installation.

"COMPARISON convinced us that a SQUARE D Control Center offered us MORE!"

These design features make Square D your logical choice, too . . .

INCREASED SAFETY because bus bars are fully enclosed, rigidly supported and have ample cross section. Circuits are isolated by individually enclosed plug-in units. Disconnect handle designed for maximum operator protection.

FLEXIBILITY. Individual plug-in units or complete sections are easily added, removed or exchanged. Pushbuttons, pilot lights, and selector switches are readily added to unit doors.

INSTALLATION ECONOMY. All wiring channels are large and accessible from front without removing units. No "wire fishing."

SPACE ECONOMY, TOO. Up to six combination starters fit in a 20" x 20" x 90" section. Plug-in unit heights designed in space-saving increments of 3 inches.

ASK YOUR ELECTRICAL DISTRIBUTOR FOR SQUARE D PRODUCTS

SQUARE D COMPANY

composed of a master station telephone located in the pump room, sub-master station telephones located in the auxiliary pump room and at the building entrance, and outlying telephones located on each of the other floors. These systems are of the common-talking type. The master and the sub-master telephones are provided with pushbuttons to selectively call each other. The master station is also provided with a loudspeaker type receiver mounted into the instrument housing. A handset with a long extension cord is included which will enable the operator of the pump to remain at his post. Vibrating bells of 6-in. size are used as audible signals on these telephones. The outlying telephones are provided with pushbuttons for selectively calling the master and the sub-master telephones. A typical riser diagram of a fire-line signal and telephone system is shown in a building in Fig. 3.

Watchman's tour systems are considered very necessary. Where the building is a part of an industrial group the signals may terminate in the guard's quarters. Where the building is separate, the signals should terminate in the superintendent's office. In general the system may be of the same type outlined under industrial buildings.

Sprinkler alarm systems are also used for the same purpose as outlined under industrial buildings. However, in office buildings these systems are usually installed in storage spaces and other hazardous locations where a deluge is found necessary to prevent the spread of a fire. It is not usually considered where water might completely damage the contents in a given location.

Smoke detection systems may be used in the various duct systems in ventilating and air-conditioning the building and may be applied as outlined under industrial buildings.

Protective alarms are provided in numerous forms. Those used to protect doors, windows, floors, ceilings, etc., in the same manner as described under industrial buildings.

Call systems are widely used and are of many types. Individual return-call systems, in which pushbuttons and a buzzer may be combined in one block for calling back and forth, are used between two points. Other systems may be composed of pushbutton blocks on

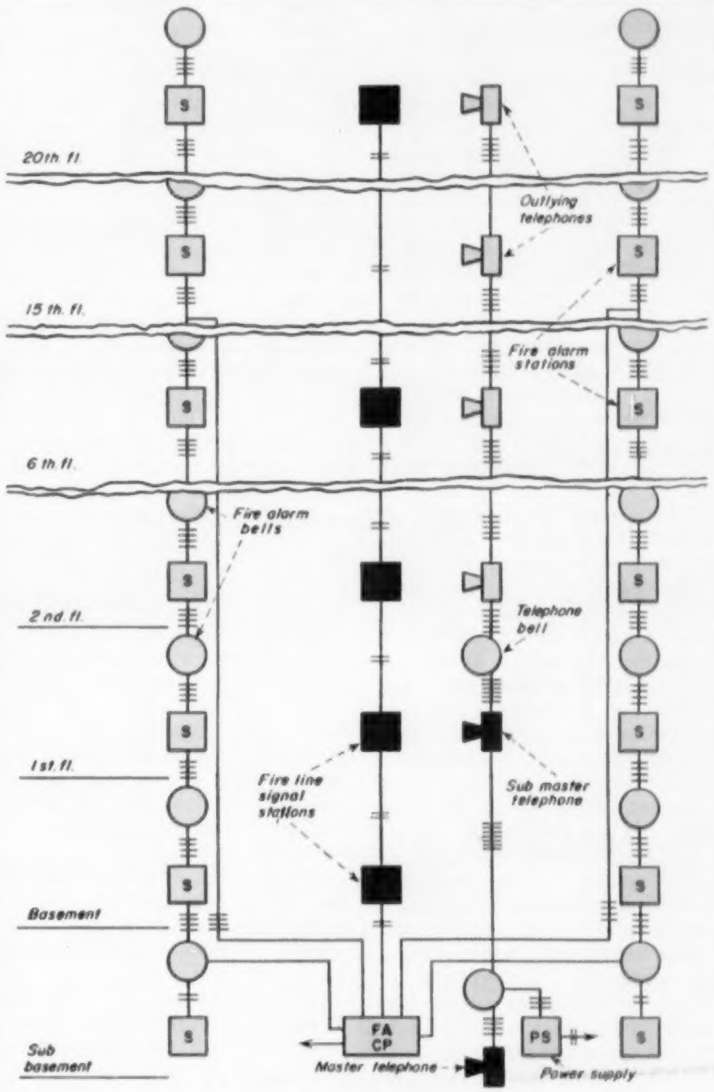


FIG. 3 – RISER DIAGRAM OF FIRE LINE SIGNAL AND TELEPHONE SYSTEM

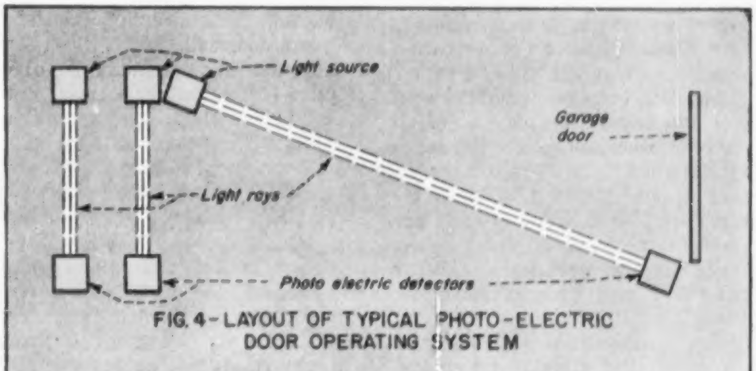


FIG. 4 – LAYOUT OF TYPICAL PHOTO-ELECTRIC DOOR OPERATING SYSTEM

desks, counters, etc., which will operate lamps or drops in annunciators, and pilot or return signals such as lamps on the originating calling station. In certain types of buildings where doors are to be supervised, it is necessary to install electric door locks on doors and release them from pushbuttons at specified locations. Electric door closers may be used and operated from pushbuttons where executives desire to close the doors for privacy.

Clock and program systems may be used in an entire building if occupied by one concern, or by the tenants occupying individual floors. The applications are the same as described under industrial buildings.

Garage ramp systems are composed of photo-electric equipment and arranged so that the doors will automatically open to permit an automobile or other vehicle to enter. A double ray is used so that the beams will not be affected or interrupted by a person who may be passing. A diagonal ray may also be used to prevent the door from lowering while the vehicle is still in the ramp. A bell signal may be located in the garage to advise attendants that a vehicle is to enter. A typical photo-electric door operating system is shown in Fig. 4.

Intercommunicating telephone systems will permit contact with various departments without causing confusion, interruptions or tying up the regular public telephones. These may be secured in different types either the amplified or non-amplified, master selective-ringing common-talking, selective-ringing common-talking, selective-ringing selective-talking, manual switchboard and automatic dial. Lamp signals may also be combined with many of these systems for special purposes. The selection of the system depends upon the number of stations to be used, whether or not more than one conversation will be held at one time, whether the system is to be under the control and supervision of an individual or whether selectivity is to be obtained without the supervision of an attendant. Other features such as conference calls are also obtainable.

Signals are most important for passenger and freight elevators. These consist chiefly of "up" and "down" pushbuttons on every floor except on the extreme lower and upper floors, with associated annunciators in the elevator cabs. These are usually supplied by the elevator manufacturers. All passenger elevators should be equipped with telephones for emergency purposes so that a conversation may be had with the starter on the main floor or the superintendent of the building. A dispatch signal system should also be included for starting the elevators and for signaling at points along the route. For dumbwaiters, two types of signals are generally used. The simplest consists of a pushbutton plate adjacent to each dumbwaiter opening having a number of pushbuttons equivalent to the other stations to be called. A buzzer is included in each station as a signal. Where one point of distribution is to be maintained, a master plate having a pushbutton for each outlying station and a buzzer is used. All outlying stations have a plate with one pushbutton and a buzzer. This will permit the master pushbutton station to call the outlying stations, while the outlying stations may call the master station. Telephones may also be used in dumbwaiter systems with the advantage of being able to converse between the points involved.

Door signals are usually used between the front, rear and boiler room entrances, to such locations as the main lobby, elevator shafts, superintendent's office and boiler room. All exterior pushbuttons should be of the watertight type. All bells should be of the heavy-duty type.

School Systems

All modern schools require signaling and communication systems which will act as aids in properly and efficiently administering such institutions. Adequate equipment properly designed and installed will give the best results and will conserve the time of students and the teachers.

Safety is the prime consideration as schools are occupied in many cases by children of all ages. High schools, vocational schools and colleges, although occupied by students of a mature age, are equally in need of efficient and reliable protective systems, as such buildings are very large. In the case of many colleges, they are located in small towns where adequate fire fighting apparatus is not always adequate.

In general there are several types of systems used in schools: manual fire alarm, automatic fire alarm, sprinkler alarm, clock, program, telephones, sound and radio distribution, lecture call, orchestra call, and door call.

Any fire signal should be distinctive from all other signals, and should be audible to everyone in the building. The apparatus for sounding the alarm should be generously distributed within the path of escape, and should be equipped for fire drill purposes. So-called fireproof or fire-resistant buildings do not decrease the need of properly drilled students. Even a small fire may fill the corridors with smoke and may result in a panic.

Fire alarm systems for use in schools are usually of four types, having one common characteristic —they are all closed-circuit electrically supervised. In small schools, either the non-coded or master coded types are frequently used. In the first system, non-coded breakglass stations operate vibrating bells or horns continuously. In the second system, non-coded breakglass stations operate an electrically tripped master movement on the control panel which in turn operates either single-stroke bells or horns, sounding a common coded signal such as 4-4. In large schools and colleges, the coded types of system are used wherein every station transmits its own distinctive code to the sounding devices. Where a number of buildings are involved, the coded type systems may be modified and extended to a group system, wherein a fire in one building need not disturb students in other buildings. The operation, therefore, of a station in one building sounds all signals in the same building and only operates signals at certain other locations where supervisors and other members of the staff take command. Auxiliarized systems, wherein the signal is also transmitted to the municipal fire department, may also be provided and is preferred in many communities. The stations used in this auxiliarized system are provided with a special lock which enables a fire drill to be made with assurance

Specify PHELPS DODGE HABIRITE-INSULATED ARMO-LOK CABLE

Phelps Dodge Armo-Lok cable with Habirite (butyl rubber) insulation—a companion to Phelps Dodge Varnished Cambric insulated interlocked armor cable—is more than "just another interlocked armor cable."

Habirite—developed through years of Phelps Dodge experience in the design and manufacture of high voltage cables — is a specially engineered butyl rubber compound. It far surpasses any other type of rubber insulation for dependable service.

Habirite offers these distinct advantages over other rubber insulations:

- Far greater resistance to heat and oxidation with consequent higher temperature rating and lower conductor size and cable cost.
- Far greater resistance to ozone found around high voltage equipment.
- Far greater mechanical toughness.
- Better electrical properties affording a greater safety factor in operation.
- Highest uniformity due to controlled uniformity of raw material.

★ ★ ★

See your Phelps Dodge distributor for information on a complete Armo-Lok system. For catalogue and specification data on Habirite or Varnished Cambric insulated Armo-Lok cable, write: Dept. E-5, Phelps Dodge Copper Products Corporation, 300 Park Avenue, New York 22, N. Y.

PHELPS DODGE COPPER PRODUCTS CORPORATION

SALES OFFICES: Atlanta, Birmingham, Ala., Boston, Buffalo, Charlotte, Chicago, Cincinnati, Cleveland, Dallas, Detroit, Fort Wayne, Greensboro, N. C., Houston, Jacksonville, Kansas City, Mo., Los Angeles, Milwaukee, Minneapolis, New Orleans, New York, Philadelphia, Pittsburgh, Portland, Ore., Richmond, Rochester, N. Y., San Francisco, St. Louis, Seattle, Washington, D. C.

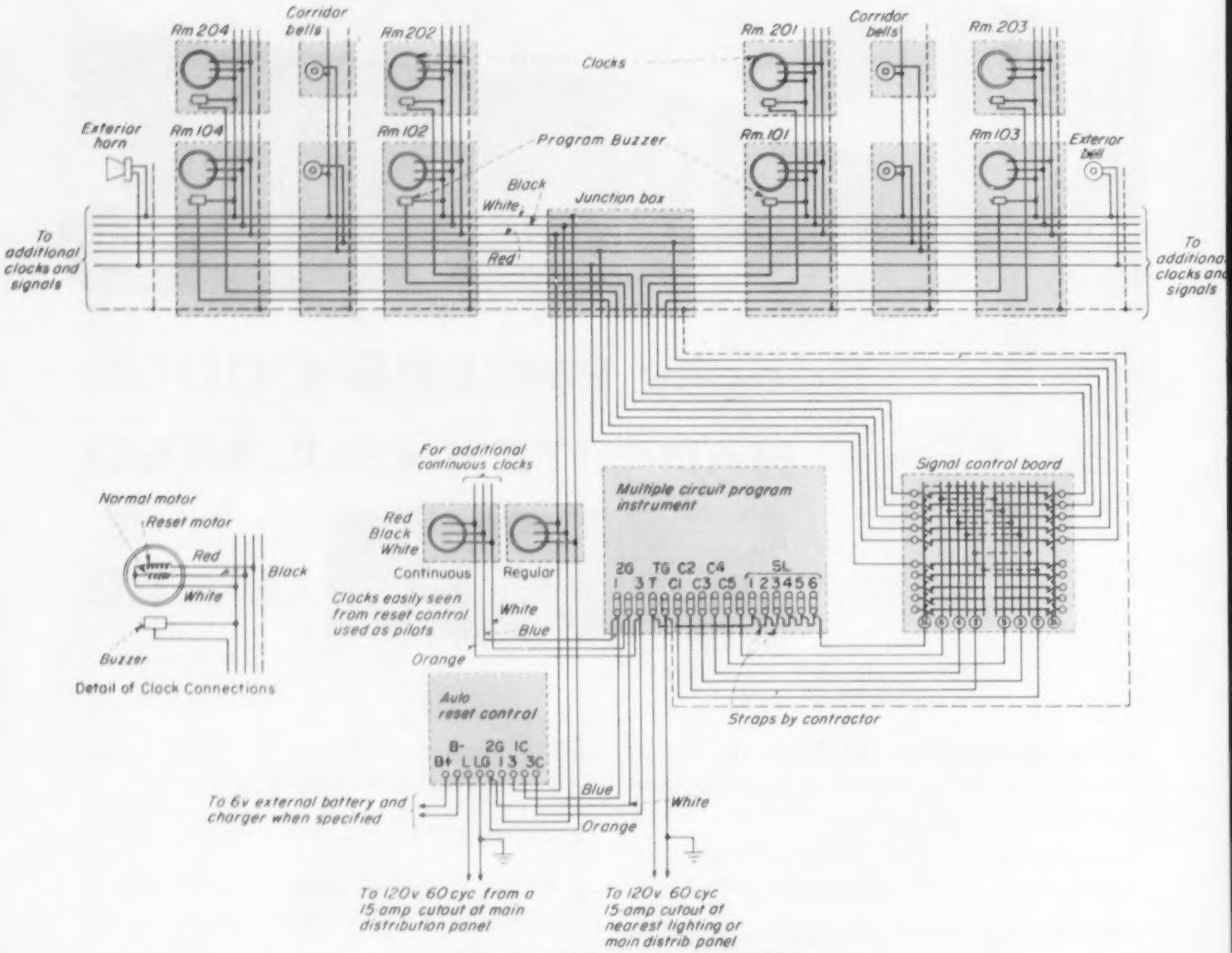


FIG. 5-CLOCK AND PROGRAM SYSTEM

that the signal will not be transmitted outside the building.

Automatic fire detection systems may be included and interconnected with any of the manual fire alarm systems mentioned above. The thermostatic detectors are generally located in the boiler room, kitchen and storerooms. In older schools having attics, this form of protection is very important.

Sprinkler systems may be used in some areas in the school buildings where the fire hazard is considered great, such as in storerooms. The alarm systems may be combined with the manual fire alarm systems or they may be self-contained. When combined with the fire alarm system an electrically tripped transmitter is connected to the sprinkler valves or waterflow valves, and the signal is transmitted over the interconnected fire alarm wiring to the same audible signals. When it is isolated from the fire alarm system, the wires are brought from the sprinkler control valves and waterflow valves directly to a separate control panel. This panel indicates the source of the alarm on indicators or drops. An audible signal such as a bell is also located near or adjacent to the control panel.

Clock and program systems provide the means of showing correct time throughout the premises, and to denote the different periods in a day's schedule. In grade schools, the programs are generally arranged to operate signals at the start of classes in the morning, morning recess, lunch period, afternoon recess and afternoon dismissal. In high schools and colleges the changes in class periods and evening classes must also be considered in setting up the ringing schedules. Program instruments are provided for any minute interval over a 24-hour period.

The clock systems are available in different forms or types, namely, minute-impulse master control, synchronous-motored master control, dual synchronous-motored and electronic. The minute-impulse system consists of a master clock and a number of secondary clocks and is operated on direct current through a rectifier. The master clock sends out electrical impulses every minute and in addition sends out correction impulses each hour to the secondary clocks. The synchronous-motored master control system consists of a master clock and secondary clocks which are synchronous motored. The master clock corrects the secondary clocks each hour within specified limits. The dual synchronous-motored system has no master clock as such but instead all clocks have two motors, one to

Multiple sale item—market scarcely touched

Exide Lightguard® emergency lighting equipment

When power fails and lights go out, Exide Lightguard emergency lighting units go on—instantly and automatically. Plug into regular outlets. Built-in charger. Batteries last for years. Several models.

Knock on any door today where people congregate. Chances are you'll find a customer for Exide emergency lighting equipment. Risk of heavy losses from panic, theft or injury is making it increasingly necessary. Some areas require emergency lighting equipment by law.

HERE'S YOUR MARKET: stores, office buildings, schools, theaters, factories, laboratories, restaurants and institutions. Most buyers need several units. So every sale can be substantial. And the tremendous potential has as yet scarcely been tapped.

BECOME AN EXIDE DEALER. Get in on the ground floor. Sell Exide Lightguards—foremost in the field for quality and acceptance. Send the coupon today.

Exide® Industrial Division
The Electric Storage Battery Company, Philadelphia 2, Pa.

Send details on Exide Lightguards

Name__________

Street__________

City__________ Zone_____ State_____

My business is__________

16

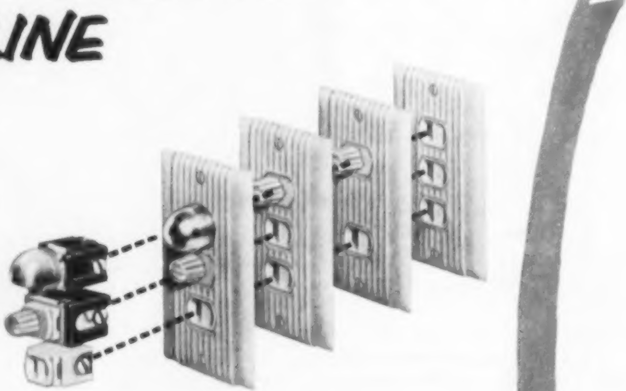
FROM SPLIT-LEVELS TO SKYSCRAPERS

P&S Wiring Devices Fill All Your Needs!

Look no further! When you need wiring devices, it's easiest to order from the *complete* line – Pass & Seymour. There is a P&S wiring device to fit *every one* of your needs *exactly*—and they're all famous for durability and performance. Whether Turnlok,® Polarized,® specification type or standard outlets . . . whether your switch needs are for residential lighting, heavy-duty, motors, commercial installations or the super-smart ROTO-GLO® . . . the best wiring devices, in *every* price range, come from Pass & Seymour.

P&S DESPARD® LINE

To meet specifications for almost every type of commercial and residential installation, nothing beats the versatility and compactness of P&S Despard devices. Up to three interchangeable switches, outlets, pilot lights or special devices fit in a one-gang, standard size plate. Assembled quickly, on the job, to fit each particular situation. No need to carry large inventories of standard outlets and switches!



They're Interchangeable!

For complete details, write Dept. ECM-14

P&S® PASS & SEYMOUR, INC.
SYRACUSE 9, NEW YORK
71 Murray St., New York 7, N. Y. 1229 W. Washington Blvd., Chicago 7, Ill.
In Canada: Renfrew Elec. & Refrig. Co., Ltd., Renfrew, Ontario

operate the hands in a normal manner and speed, the other to operate at a much faster rate and which in turn is used to advance the clocks to correct time after an interruption in the current supply. The electronic system consists of a master clock or transmitter and a number of electronic secondary clocks which operate on a specified electrical frequency and are controlled once each hour by the master clock.

Program systems consist chiefly of a program instrument, a selective signal control board and the necessary audible signals such as bells or buzzers. In sound systems, the bells and buzzers are replaced by an oscillator and loudspeakers. The program instrument is composed of a calendar drum or device, a time drum, signal circuit relays, signal control switches, and program-circuit pushbuttons. In a small system, the audible signals may be controlled directly from the program instrument. In the larger systems where selectivity is required, a signal control board is used having a pushbutton for each signal device and a set of program cross-connecting busbars with plugs, which permit the changing of any pushbutton from one program circuit to another. In systems incorporating telephones with the signal control board, a handphone is added to this board for communication from the main office to the classrooms and other locations having telephones. The pushbuttons on the signal control board are used for ringing the outlying telephones which actually use the program buzzers in the clock cases as their signal. The program bells in the corridors, auditoriums, gymnasiums and boiler rooms are usually 6 in. in size. In other locations such as locker rooms and shops, the 4-in. size is used. Exterior bells should be of the 10-in. weatherproof type with full cast grids or housings. A clock and program system is shown in Fig. 5.

Elapsed-time clocks may be secured to indicate the time taken by various phases of experiments in laboratories, or the elapsed time in sports such as basketball, football, track, swimming, etc. These are connected individually and are not considered a part of the clock systems.

Telephones are used for intercommunication between the principal's office and the main office and the classrooms. This may be accomplished by means of a master system having a central telephone in which the pushbuttons are used to call the outlying telephones each of which have an audible signal enclosed within the instrument. Or the signal control board of the program system with a handphone and the associated control equipment may be used as the master, using standard outlying telephones with their enclosed signal or outlying telephones without a signal, in which case the program buzzer in the clock cases would be used as a signal. The classroom telephones are usually of the wall mounted type, while those in the principal's and assistant principal's offices would be of the handphone-on-cradle type. In large high schools and colleges, a manual switchboard system or an automatic dial type system is often used. In the former, the operator would have full control of the traffic between all points. With the automatic type, each person using the system may dial to secure any telephone.

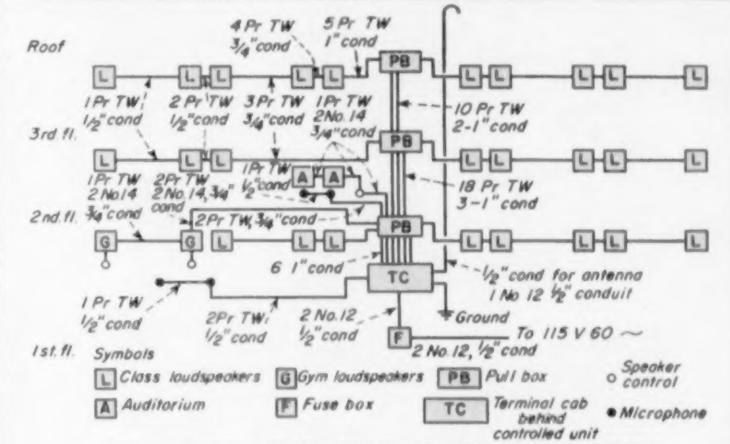


FIG. 6 -TYPICAL SOUND AND RADIO DISTRIBUTION SYSTEM RISER DIAGRAM IN SCHOOL

Sound and radio distribution systems are used in all types of schools. These systems consist chiefly of a control desk, microphones and loudspeakers. The control desk may be located in some special room near the principal's office. It is composed of individual control switches for each outlying loudspeaker in classrooms, auditorium, gymnasium, athletic field, etc., together with monitor speaker, microphone, record turntable, radio receiver, amplifiers and other control devices. The microphones are located at the control desk, principal's office and stage with outlets at other points as selected. The loudspeakers are located in the classrooms, auditorium, gymnasium, corridors, cafeteria, athletic field, etc. The system enables the distribution of radio programs, recordings, lectures and announcements to all points selectively or collectively. If desired the talk-back feature may be included which will permit conversations to take place between the monitor speaker at the control desk and the loudspeakers in any classroom. A typical sound and radio distribution system is shown in Fig. 6.

Lecture call systems are in reality return-call systems and are used between the stage in the auditorium and the projection booth. Most of these systems consist of a station on the stage, installed on the wall or in the floor. A long portable cord with a detachable plug and a pendant pushbutton is a part of this station and is used for calling the projection booth where a buzzer is sounded. A buzzer is mounted on the wall of the stage and is controlled from the station in the projection booth which consists of a pushbutton mounted on the wall, ganged with the buzzer used for calling from the stage. A pilot light may be added to the projection booth station with a switch so that either the buzzer or the pilot light may be operated. Tele-

phones may also be combined in these systems.

Orchestra call systems are usually return-call systems in which lamp annunciators with a buzzer and pushbuttons are used, and these are located in the orchestra pit. Outlying stations consist of stations with a buzzer and pushbutton or a pilot lamp and pushbutton and are located at the stage lighting switchboard and in the projection booth.

Dressing room call systems are similar to the return-call systems mentioned previously. The annunciator is generally located at the stage lighting switchboard and the return-call stations are located in each dressing room.

Hospital Systems

Hospitals use a wide variety of signaling and communication systems which are essential to their efficient operation. The equipment has been designed to facilitate service to the patient and to preserve the energy of the nurses and other attendants. The safety of the patients, nurses and other members of the hospital staff has also been considered in the design and the type of systems available.

There are several types of systems used in hospitals, namely visual and audio nurse-call, emergency calls, psychopathic alarms, paging, "In" and "Out," sprinkler alarms, intern, ambulance, clinic, inter-phone, nurses'-home room-calls, clocks, laboratory, fire alarm, watchman's report, elevator and dumbwaiter signals, door-calls and ground detector signals.

Nurse-call systems are used by the patients to call a nurse or attendant to the bedside. There are two general types of such systems —the visual and the audio. By pressing a portable button, lights are caused to be illuminated over the patient's door in the corridor, duty rooms, diet kitchens and the nurses' stations on a given floor or section thereof. In the case of a ward, a pilot light is included with the calling station or is mounted on the ceiling above the curtained cubicles to ascertain the origin of the call. The lamp signal at the nurse's station may be a single common lamp for a floor, or a section thereof, or an annunciator with an indicating lamp for each room. The choice depends upon the number of rooms, shape and size of the floors, the number of nurses available, and the amount of efficiency desired. In addition to the lamp signals, a buzzer is located at each supervisory point such as duty rooms, diet kitchens and nurses' stations together with a cut-off switch permitting full control at all times. In large hospital, it is also at times desirable to install supervisory annunciators at the chief nurse's quarters which may have duplicate signals of those shown in the annunciators at the regular nurses' stations.

Directional pilots are of assistance when used with nurse-call systems. They are used to direct attention to the nurses while en route between patients' rooms and points of supervision. They indicate the general direction of a call without having to return to a supervisory point. These signals consist of door-lamp stations mounted on the ceiling of a corridor intersection and may be interconnected with other floors.

Nurse-call stations of the visual and audio type using locking buttons may be ganged with other outlets such as radio, public tele-

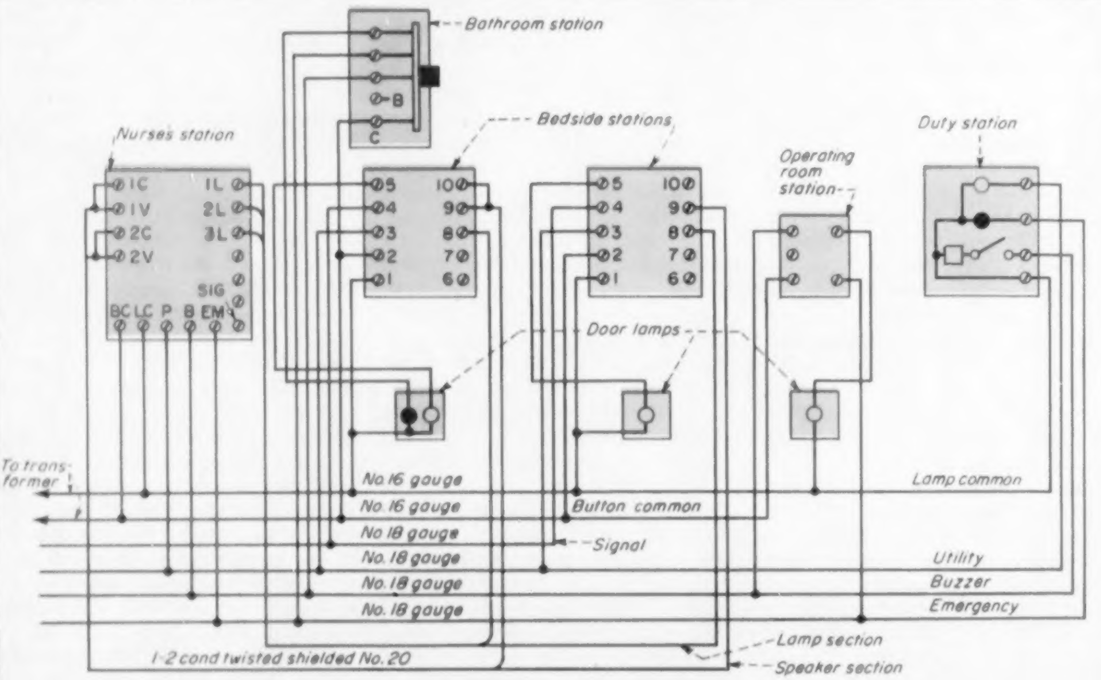


FIG. 7- AUDIO-VISUAL NURSE-CALL SYSTEM WITH AUTOMATIC RESET

phones, duplex convenience receptacles, night lights, etc. A barrier must be provided in the outlet box whenever a lighting circuit enters adjacent to a low-tension outlet. However, nurse-call stations of the visual and audio remote-reset type use momentary-contact buttons.

The audio or voice feature is used in conjunction with the visual nurse-call system and is a valuable adjunct since the nurses may converse with the patient and in that way can give better service and save considerable time and footsteps. In this system, the patient presses the pushbutton in the usual manner and all lights and buzzers operate as previously described. The chief change is at the nurse's station, where in a new installation the annunciator is omitted, since the lamps, the control and the audio equipment is enclosed in one unit. A loudspeaking unit is located in the wall at the head of the bed or on the night table alongside the patient's bed. When the patient presses the button, a lamp illuminates in the master unit at the nurse's station. A control key for that station or room is operated by the nurse and the circuit is completed for talking. All other lights in the corridor and supervisory points remain illuminated until the button is reset at the patient's bedside in the case of locking button systems, or reset at either the patient's bedside or at the nurse's station in the case of the momentary-contact button type. A typical wiring diagram of a visual and audio nurse-call system with automatic reset is shown in Fig. 7.

Emergency Call

An emergency feature may be added to any nurse-call system. This is in most cases used by the nurse to call assistance to a patient's room when the occasion requires. In the case of a locking button nurse-call system, the emergency button has the same contact mechanism as the portable button; but it is mounted directly in the gang plate. When this button is operated it illuminates separate and distinct lamps and audible signals. As an example, a red or green lamp is added to each corridor lamp station and to all supervisory stations. In addition a bell, which operates continuously, is used.

Psychopathic alarm systems are used as a protection in the event a nurse or attendant is attacked by a violent patient. Such a system consists of corridor-control stations, room-calling stations, corridor lamps and supervisory stations as for the regular nurse-call system. When an attendant enters a room, the corridor control station is set by means of a key before going into the room. This immediately energizes the room stations within that room and lights a clear lamp in the corridor door lamp and at the supervisory points. Should it become necessary to call for assistance, the room stations are operated by means of a pushbutton which lights colored lamps at all points described previously and operates a bell continuously at the nurse's station and at other points desired. The system is de-energized by resetting the corridor station.

Paging Systems

Paging systems are used to locate doctors and other members of the staff throughout the building. There are three general types of systems used: visual, sound and coded. The visual system uses lamp annunciators throughout, but also incorporates an audible signal such as a buzzer or chime in the event an occasional selective signal is desired. The sound system consists of loudspeakers throughout. The coded system uses bells, buzzers, sounders or chimes throughout. In the visual type, three and as many as six persons may be paged at one time by setting up the combination of code numbers. Usually three digit figures are used, although occasionally one, two, three or four digits are used to increase the code number combinations. In the sound system, the name of the person is transmitted through microphone. In the coded system each person is assigned a code number which is transmitted from a central point to all audible signals.

"In" and "Out" systems are used by the doctors and other members of the staff to designate whether or not they are present in the building. Generally, an entrance register, having a lamp and a switch for each person, is located near the main entrance of the building or in the doctors' cloak or lounge rooms. Another unit known as the office register and having the same capacity, is located near the telephone switchboard operator. In the standard type system the office register does not require switches, but in the recall or message type system, a switch adjoins each lamp, the same as for the entrance register.

In the system using the entrance register and the regular office register, the doctor operates the switch alongside his name and this causes the lamp to illuminate his name at the entrance register and at the office register. When he leaves the building he returns his switch to the original position in order to extinguish the lamps. In the message signal type, the operation of the switch in the office register by the telephone switchboard operator causes the connected lamp to flash in both units and indicate that such a person is wanted at the office to obtain a message, instructions or mail before leaving the building. A typical "In" and "Out" system is shown in Fig. 8.

Sprinkler alarm systems are used in localities where it is deemed necessary to deluge the contents of a room to insure against spread of fire from one point to another.

Intern-call systems generally consist of either a return-call system or a master telephone system between the interns' living quarters and the head nurse's or superintendent's office. In the return-call system a pushbutton board with a buzzer is located at the central point, and a return-call station consisting of a buzzer and pushbutton is located in each intern's room. Added features would be indicating drops in the room stations and in the unit at the central point. The system is used to call the interns to the nearest telephone. A handphone may be added to any of these units to insure direct conversation.

Ambulance Calls

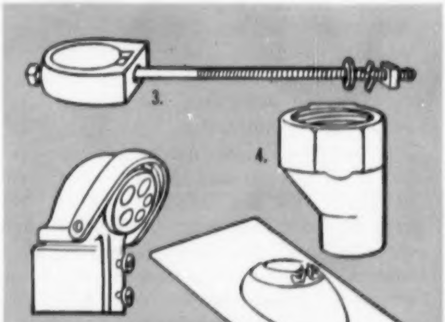
Ambulance calls may be kept separate but are often combined on an annunciator with other door signals. In most cases, however, the system is so arranged that a bell operates with the annunciator indicator as a distinctive signal when a pushbutton is operated from the ambulance entrance.

Clinic systems are generally composed of annunciator or buzzer call systems. In the case of examination and dressing rooms, a pushbutton plate is located in the former having a pushbutton for each dressing room. A buzzer is located in each dressing room. The signal designates that the doctor

Hubbard Service Entrance Mast Kit

The new Hubbard Service Entrance Mast is your answer to the low roof service problem. Because it is designed to conform to the latest service entrance practices, local requirements can be met with a minimum of time and expense. Easily assembled with only a few electrician's tools, the installation is fast, weather-tight and permanent.

Two complete kits are available for use with 2-inch or 2½-inch conduit risers. Each kit contains Slip-fitter Entrance Head (1), Galvanized Roof Flashing (2), two Mounting Brackets (3), and Offset Reducer (4) for Meter fittings. All accessories necessary to meet local installation requirements are available and must be specified separately. For complete information write for copy of Bulletin P-1255.



HUBBARD AND COMPANY
Pittsburgh 1, Pa.
Chicago 50, Ill.
Oakland 3, Cal.

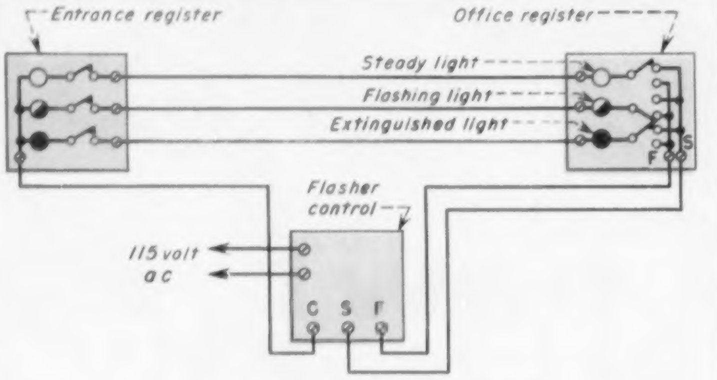


FIG. 8 – "IN" AND "OUT" SYSTEM

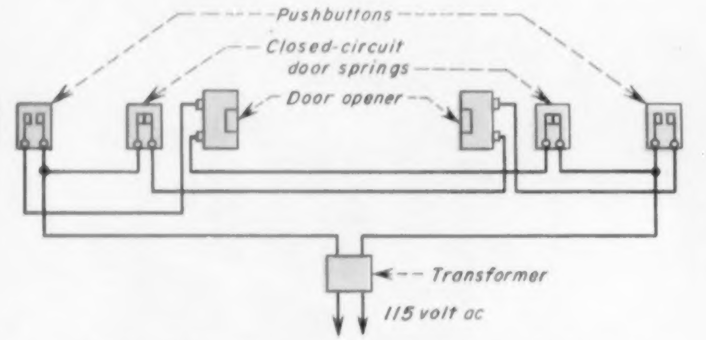


FIG. 9 INTERLOCKING DOOR SYSTEM FOR LABORATORIES

is waiting for a specific patient. In the case of examination room, dressing rooms and nurse's station, pushbuttons may be placed in the rooms while an annunciator is located at the nurse's station. A call from the examination room would designate the available rooms. A call from the dressing room would designate the patient ready for examination.

Interphones are used between the main kitchen and the floor diet kitchens and are usually located near the dumbwaiters. They may also be used between the offices, nurses' stations, supervisors, etc. For the kitchen service, a master system may be used wherein the master telephone may be located in the main kitchen equipped with a pushbutton for each outlying telephone. The outlying telephones are provided with a single pushbutton. In this system the master telephone can call any of the outlying telephones, but the outlying telephones can only call the master. For intercommunication between a small number of offices and various departments, a selective-ringing common-talking system may be used. In larger systems using more than 12 telephones a selective-ringing selective-talking system should be used.

Nurses'-home calling systems are composed of the same equipment as previously described under interncall system. In very large nurses' homes, the central control unit should be of the plug and jack type wherein a telephone type jack is used for all rooms having the same last two digits in their room numbers. The wiring in this system is greatly simplified and results in a large saving for installation.

Clock systems are very important in hospitals, both for keeping time and in administering anesthesia. The types of systems available are the same as previously described under school systems. They are located in offices, corridors, nurses' stations, kitchens, laboratories, operating rooms, lounges, etc. Seconds-beat clocks should be installed in operating and delivery rooms.

Dining room call systems consist of a series of pushbuttons distributed throughout the dining rooms for doctors, nurses and other members of the staff, with annunciators located in the kitchen or dietician's office. The annunciators indicate the origin of the calls.

Laboratory signal systems are used for various purposes. Contacts may be placed on the doors of cabinets which contain drugs, narcotics, etc., and the signals may be transmitted to an annunciator located in the office of the person in charge. An interlocking door control system may be provided on the doors leading to the dark room for the development of X-ray films. This is so arranged that no one may enter such a room unless an inner or another entry door is closed to insure that bright light does not enter the developing room. This system consists chiefly of electric door locks, pushbuttons and door contacts. A typical system of this type is shown in Fig. 9.

Fire alarm systems for use in hospitals are usually of the presignal type. In this type of system the first operation of the pull lever in the coded station only operates pilot bells at certain supervisory points such as the superintendent's office, chief nurse's office, engineer's office, elevator shafts, etc. Upon arrival at the point of the fire, if it is deemed necessary to vacate the building, the officer in charge inserts a plug in the station alarm jack and pulls the lever so that all bells throughout the building operate. Occasionally a regular coded system is used and chimes are located at the nurses' stations and at supervisory points. Where several buildings are involved a group system such as previously described under industrial systems is preferable, using the pre-signal equipment in the hospital building. Automatic fire alarm equipment may be used in storerooms and other hazardous locations and interconnected with the manual fire alarm system as described in other sections.

Watchman's report systems are used in hospitals to insure that the premises are covered properly at night. The types of systems described in other sections may be used for this purpose.

Sound and radio systems enable

why refuse this help when it's time *to* RE-FUSE

You may need new fuses because . . . you're expanding your equipment . . . or adding new circuits . . . or maybe your present fuses have been blowing too frequently.

No matter what the reason, before you buy new fuses, call your electrical wholesaler who carries ECONOMY FUSES . . . especially if you're in doubt or have an unusual fuse problem.

Your electrical wholesaler will advise you which ECONOMY FUSE is best suited to your particular need. If the problem is unusually difficult, he can draw on the experience of ECONOMY engineers who have encountered every kind of fuse situation during the more than 44 years of the company's history.

Ask for the Complete Line Folder No. 3

If your electrical wholesaler is out of them, write to us or simply check the coupon below. Also check for catalogs or special bulletins you want.

ECON®

dual-element fuses offer dual-protection

1. Time-Controlled Protection against unnecessary blowouts from temporary and harmless overloads
2. Instantaneous protection against short circuits

ECONOMY FUSE & MANUFACTURING CO.

a few of the many other Economy Fuses and fuse accessories...

Economy DELAY Renewable® Fuses and Renewal Links

Renewable Plug Fuses

Clearsite "Shows when it blows"

Fuse Pullers

Clip-Tite Fuse Clamps

——For special Bulletins on any of these Check and Mail This Coupon——→

INFORMATION COUPON

ECONOMY FUSE & MFG. CO., 2717 Greenview, Chicago 14, Ill.

Please send me, without cost or obligation, bulletins on the following fuse products.

___ECON Dual-Element ___Economy DELAY Renewable

___Complete Line Folder No. 3 ___Renewable Plug

___Pullers ___Clip-Tite Clamps ___Clearsite

NAME________________

COMPANY NAME________________

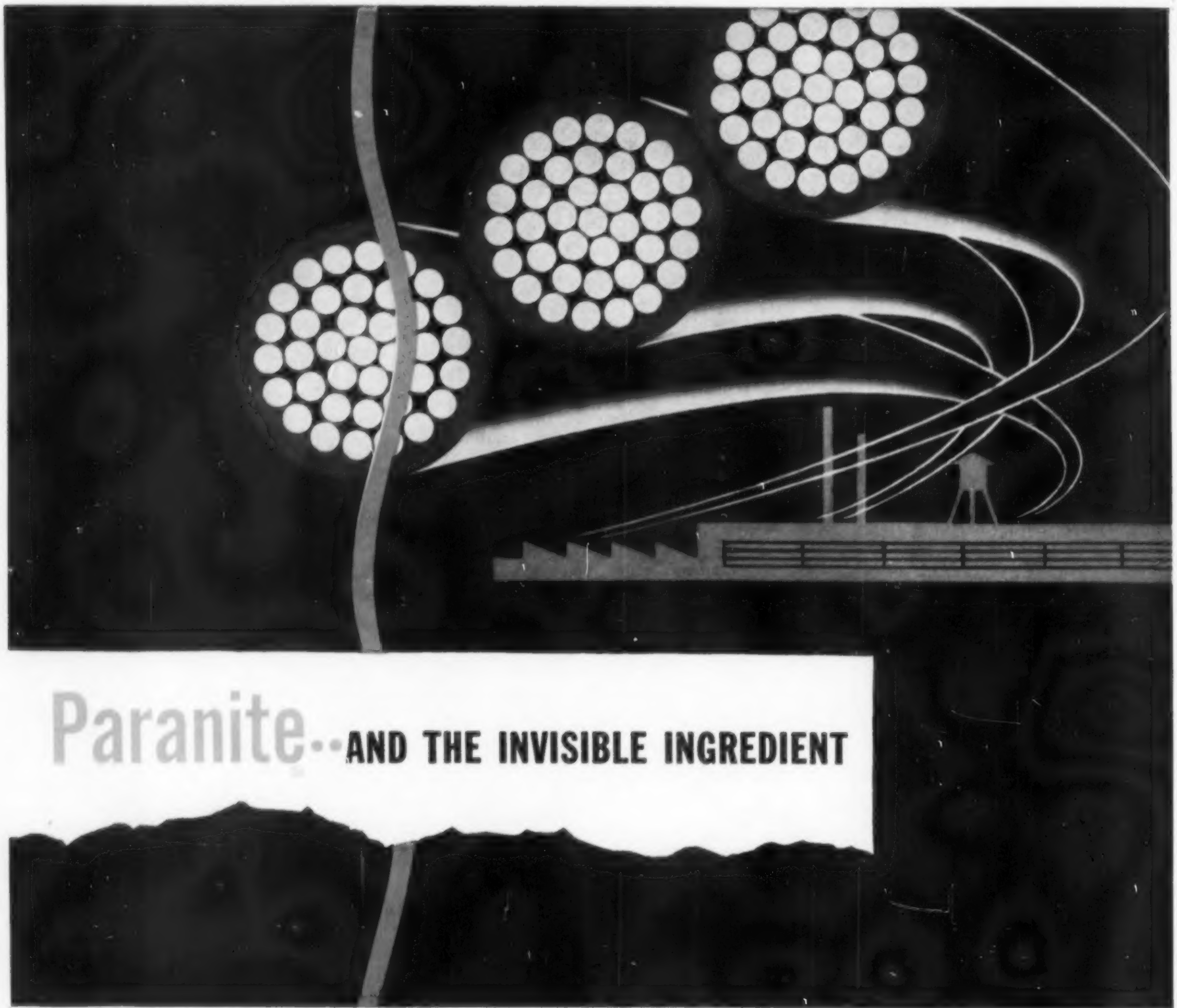
STREET ADDRESS________________

CITY________ZONE____STATE____

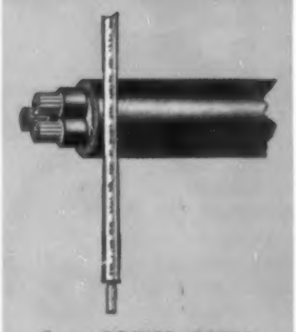
For FUSE ECONOMY Use Economy Fuses

SEE YOUR ELECTRICAL WHOLESALER

1087R



Paranite... AND THE INVISIBLE INGREDIENT



● Manpower is essential to production... but what is more important is the attitude of the individuals who comprise that manpower. At Paranite, you will find everyone sincerely interested in his part in the manufacture of our wire products.

This conscientious attitude is difficult to see... or feel... yet it contributes much to the high degree of perfection Paranite products have reached. This, we believe is another important phase of the *invisible ingredient*.

With an entire organization striving to produce each day a better product than the day before, Paranite has earned through the years the respect of contractors and wholesalers everywhere. In fact, these men... having long experienced the dependability of Paranite wire products... coined a phrase: "If It's Paranite, It's Right!"

So specify Paranite, knowing that the wire and cable you receive is as nearly perfect as human hands can produce... utilizing modern equipment and cautious testing. This is the *invisible ingredient*... working for you!

From POWER CABLE to FIXTURE WIRE... you'll find Paranite quality high... service outstanding!

PARANITE WIRE AND CABLE

DIVISION ESSEX WIRE CORPORATION

FORT WAYNE 6, INDIANA

MANUFACTURING PLANTS: **Birmingham, Ala.; Anaheim, Calif.; Jonesboro, Ind.; Marion, Ind.**

Warehouses* and Sales Offices

*Atlanta, Georgia; Boston, Massachusetts; *Chicago, Illinois; Cleveland, Ohio; Dallas, Texas; *Detroit, Michigan; Hartford, Connecticut; Indianapolis, Indiana; *Kansas City, Missouri; *Los Angeles, California; *Newark, New Jersey; Omaha, Nebraska; *Portland, Oregon; Upper Darby (Philadelphia), Pennsylvania; Rochester, New York; *Saint Louis, Missouri; *San Francisco, California; Seattle, Washington; Springfield, Illinois.

DESIGN DATA FOR SOUND SYSTEMS

Following is an outline of usual factors involved in laying out paging, public address and music distribution systems:

I. LOUDSPEAKERS

A. Number of speakers (depends upon size, shape and type of area)
   1. One or a few, each operating at high output (high-level speaker system)
   2. Relatively large number, each operating at low output (low level speaker system)

B. Types of speakers
   1. Cone speakers in wall-mounted, ceiling-mounted, or suspended-baffle enclosure
   2. Horn speaker (trumpet, projector horn, re-entrant horn, etc)

C. Amplifier connection
   1. Direct connection to amplifier output taps corresponding in impedance value (ohms) to impedance value (ohms) of a single speaker or of a number of speakers in series, parallel, or series-parallel
   2. Connection to amplifier constant-voltage output taps (70, 100, 140 volts, etc) through constant-voltage line-matching transformers
   3. Connection to amplifier high-impedance output taps (250 or 500 ohms) through constant-impedance line-matching transformers

D. Placement of speakers
   1. Assure uniform loudness (eliminate dead or hot spots)
   2. In churches, theatres and auditoriums, place speakers well forward of microphones to prevent feedback (squealing)
   3. Minimize reverberation (sound bouncing around)

II. AMPLIFIERS

A. Power output
   1. Typical ratings: 6, 10, 15, 30, 50, 70, 100, 125, 250 watts
   2. Output required depends upon size and type of area to be covered by sound system (see accompanying table)

B. Number and types of inputs (terminals for connecting high- and/or low-impedance microphones, record player or radio tuner)

C. Output taps (impedance values)
   1. Direct connection: 4-, 8- and 16-ohm taps
   2. Constant-voltage line transformer connection: 70-, 100- or 140-volt taps
   3. Constant-impedance line transformer connection: 250- and/or 500-ohm taps

D. Special functions
   1. Record player built into amplifier housing
   2. Amplifier, microphone and speakers in carrying case (portable system)

E. Controls
   1. Tone
   2. Anti-feedback

F. Remote volume controller (plug-in unit for use at distance from amplifier)

G. Power source
   1. 110-125 vac, 60 cycles
   2. 115 vac, 25 cycles
   3. 115 vdc
   4. 6 or 12 vdc

H. Amplifier mounting
   1. Portable, with protective cage
   2. Panel-mounted, for installation on rack

I. Cost (increases with power rating and fidelity of reproduction)

J. Separate preamp unit (for one or more remotely located power or booster amplifiers)

K. Custom assemblies (amplifier, preamp, radio tuner, record player, or other input devices mounted in vertical cabinet rack or console cabinet)

III. INPUT DEVICES

A. Microphones
   1. Crystal, dynamic or velocity
   2. Omni-directional, bi-directional, or uni-directional (cardioid)

B. Record player (automatic or manual)

C. Tape player

D. FM-AM radio tuner

E. Tone generator
   1. To produce tone signal for factory work shifts, lunch periods, etc.
   2. Electronic siren for alarm applications
   3. To simulate sound of large bell in church belfrys

TYPICAL SYSTEM DATA FOR VARIOUS APPLICATIONS

Application	Sq. Ft. Area	Amplifier Rating (Watts)	Number of Speakers	Type of Speakers
Auditoriums	2,000	15	2	12" Cone in Wall Baffles
	5,000	30	2	12" Cone in Wall Baffles or
	15,000	50	4	12" Projector Horns
Ballrooms	2,000	15	4	12" Cone in Wall Baffles
	4,000	30	4	
	10,000	50	6	
Churches	1,000	10	2	10" Cone in Wall Baffles
	4,000	15	2	12" Cone in Wall Baffles
	15,000	30	4	
Classrooms, Offices and Stores	500	10	1	8" Cone in Wall Baffle
	2,000	15	2	10" Cone in Wall Baffles
	8,000	30	4	
Factories	1,000	15	2	12" Projector Horns
	4,000	30	4	
	8,000	50	4	Re-Entrant Horns
	40,000	100	10	
Funeral Parlors	1,000	10	1	12" Cone in Wall Baffles
	4,000	15	4	
	10,000	30	8	
Restaurants and Night Clubs	1,000	15	2	12" Projector Horns
	5,000	30	6	
	10,000	50	12	
Stadiums and Gymnasiums	3,000	15	2	12" Cone in Wall Baffles
	10,000	30	4	Re-Entrant Horns
	50,000	100	8	

NOTES:
1. Values given in table are averages — not minimums or maximums.
2. Number of speakers and amplifier power rating should be increased where background noise is higher than normal for the type of area.
3. Although wall baffles are indicated for cone speakers, ceiling-recessed or suspended baffles are frequently advantageous.
4. Acoustically "live" areas generally require lower speaker sound levels.
5. Number of speakers will vary with shape of the plan view of the area.

the patients to listen in on one or more channels of radio programs, recordings, announcements, etc. Connection of the headphone or loudspeaker is made by plugging into the jack on the wall plate, usually ganged with the nurse-call station. Provision should also be made for television, the outlets being located in solariums, day rooms and lounges.

Elevator signals for passenger and freight are always provided, and are usually provided by the manufacturers of these units. Signals are also required for dumbwaiters.

Door-call systems are of the standard type providing weatherproof pushbuttons at the front, rear and boiler room doors and operating an annunciator in the office with extension bells at specified locations.

Ground detector systems are installed for each operating room in the adjacent corridors. They consist of pilot lights and ground test switches. They are used as a precautionary measure to prevent hazards caused by explosion of anesthesia when contacted with electric spark due to the presence of static electricity.

Apartment House Systems

While some of the signal systems used in the past for apartments are no longer in large demand, there are several systems considered a convenience to the tenants and others mandatory under law.

Some of the systems include manual fire alarm, sprinkler alarm, interphones, suite-call systems and television antenna systems.

Fire alarm systems are mandatory under many state and city multiple-dwelling laws and should be checked for requirements. They vary from the regular coded system to the non-coded types.

Sprinkler alarms are also required under many state and city ordinances covering multiple dwellings and like the fire alarm systems should be checked for requirements.

Interphones are used to some extent between the vestibule or lobby to the various suites and to the superintendent. They are also used in the vicinity of the dumbwaiters in the older apartments. The suite telephones are generally provided with a pushbutton for operating the door-opener at the main entrance with a second pushbutton to call the superintendent.

Suite-call systems are simple inasmuch as they consist of a pushbutton located adjacent to the door of the suite which is wired to a buzzer within the suite either mounted separately or enclosed in the housing of the telephone.

Television outlets should be provided in all new apartment suites together with the associated antenna system. The common use of more than one television set and the use of FM radios require several outlets from the antenna.

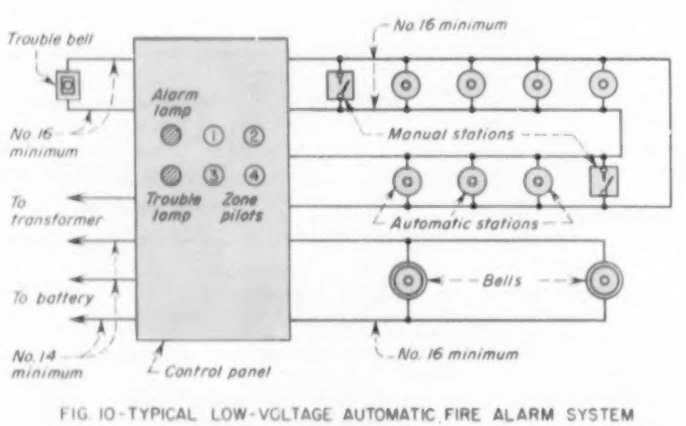


FIG. 10-TYPICAL LOW-VOLTAGE AUTOMATIC FIRE ALARM SYSTEM

Hotel Systems

Fire alarm systems for general usage should be of the manually-operated pre-signal type as previously described under hospital systems.

Automatic fire alarm systems should be located in storerooms, boiler room, kitchens and other locations presumed to be hazardous. In the larger buildings they may be combined with the manual fire alarm system. In smaller buildings they may be separate using thermostatic detectors in all rooms, clothes closets, corridors, stairwells, boiler room and kitchens, with at least one non-coded break-glass station on each floor located near stairways and other paths of escape. The system should be divided into zones using a closed-circuit supervised control panel with zone lamps, trouble lamps and alarm lamps and bells all designed for continuous operation even though the main power supply fails. Fig. 10 shows a typical system of this type.

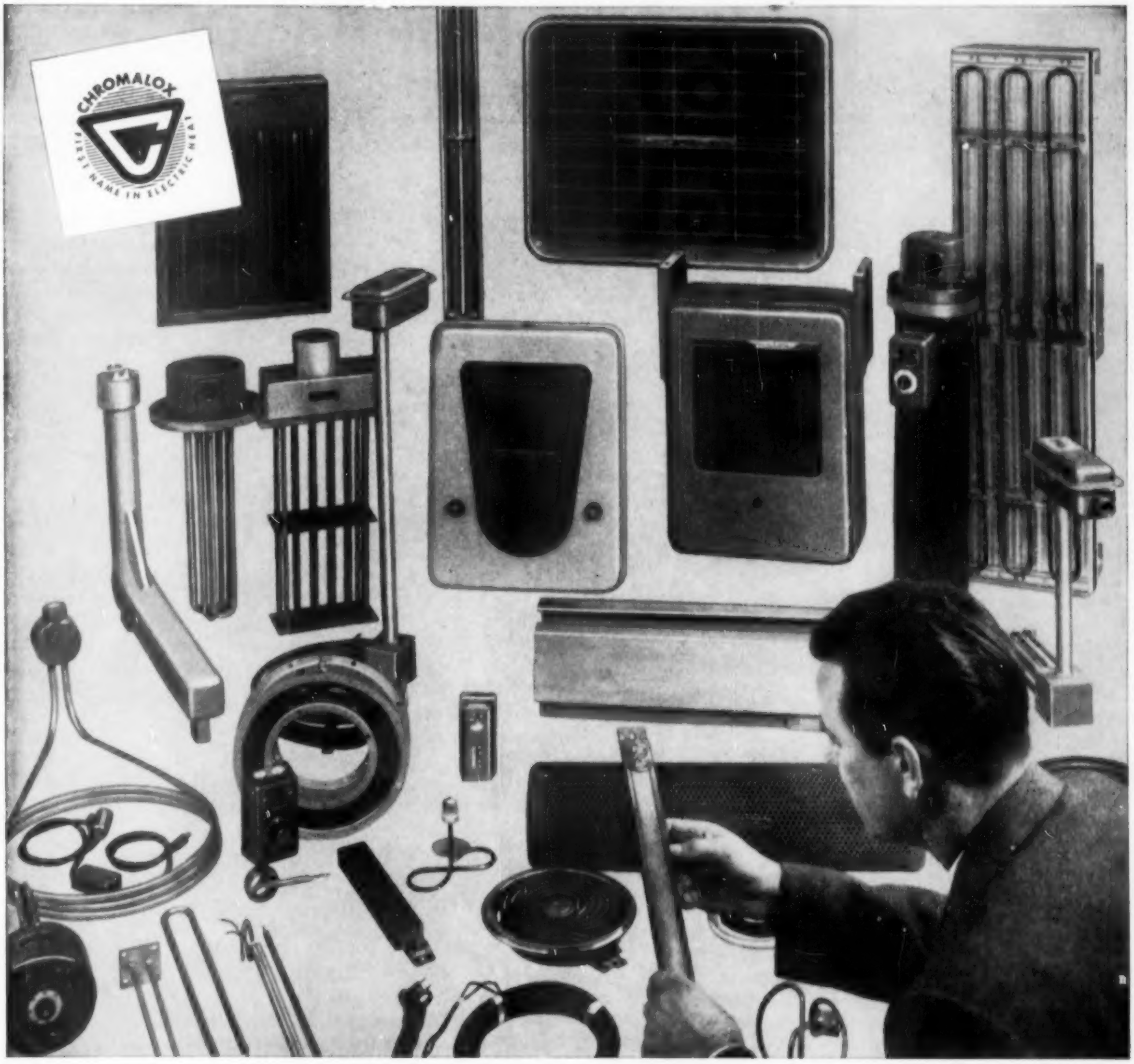
Sprinkler alarms in the larger buildings are used in the basements, storerooms and other locations of possible hazard. In the smaller buildings constructed of non-fireproof material the system may be installed throughout.

Paging systems are used by the bellhop captain for locating guests and members of the staff. They are usually of the public address type, using one or more microphones in conjunction with loudspeakers located in the lobby, lounges, grilles, coffee shop, ballroom, etc.

Clocks are essential and should be located in the lobby, offices, kitchens, engine room, ballroom, private dining rooms and grilles. They may be of the same type previously outlined under school and industrial buildings. Time stamps and employee's card recorders may be used separately or combined with the clock system.

Hold-up and burglar alarm systems may be used on cashiers' counters and vaults, in the same manner described for industrial and office buildings.

All rooms should be wired for radio channel programs and have television outlets. Lounges and grilles should have permanently connected television sets, with suitable antenna outlets.



Picture of a man with the ANSWERS!

Chromalox Electric Heating Equipment can put you in every phase of an important growing business. In the Home, Commerce and Industry, electric heating applications offer new and promising sales opportunities.

With Chromalox heating equipment, you can answer every heating problem—electrically. 15,000 standard types, sizes and ratings. World's largest stock. Available for immediate delivery. Complete range of controls and accessories. Nationwide sales-engineering service.

Find out today how you can take advantage of new sales opportunities in electric heating. Contact your nearest Chromalox representative or write direct.

Edwin L. Wiegand Company

7637 Thomas Boulevard • Pittsburgh 8, Pa.

A-4466

Edwin L. Wiegand Company
7637 Thomas Boulevard, Pittsburgh 8, Pa.

Please send me the literature checked below:

- ☐ General Industrial Electric Heating Units
- ☐ Industrial Radiant Heaters
- ☐ 101 Ways to Apply Electric Heat
- ☐ How to Solve Winter Problems with Electric Heat
- ☐ Process Air Heaters
- ☐ Electric Heaters for Electroplating
- ☐ Thermwire Heating Cable
- ☐ Cartridge Heaters
- ☐ Circulation Heaters
- ☐ Strip Heaters
- ☐ Comfort Heaters
- ☐ Electric Range and Water Heater Units
- ☐ Baseboard Heaters
- ☐ Radiant Wall Panels
- ☐ Fan Driven Wall Insert Heaters
- ☐ Hi-Flow Portable Heaters
- ☐ Utility Spot Heaters

Name ________________ Title ________

Company ________________________

Address ________________________

City ________________ State ________

Heating, and Air Conditioning

HEATING, ventilating and air conditioning equipment installations are normally designed by the project mechanical engineer in conjunction with engineers of the equipment manufacturers. Electrical engineers performing this function will also do so aided by manufacturers' engineers. Since no attempt can be made here to go into heating and air conditioning engineering, only factors affecting the design of electrical wiring to such equipment which differ in some respect from general applications will be considered.

The problem of providing sufficient heat or air conditioning for specific applications varies with the desired objective; hence wiring requirements for such loads will, as for other loads, be a function of the rating of the connected equipment. For the great variety of industrial applications of electric heat, requirements may be summarized generally by (1) the amount of heat necessary to raise the solid, liquid or gaseous material involved to the operating temperature and (2) the heat required to maintain temperature.

Due to the heat retentivity of building materials and the continuous nature of space heating loads, the initial heat to bring the space to temperature is not normally considered, design being based merely on the heat necessary to offset that lost by convection, conduction and radiation through the building itself to the outside.

Equipment capacities for electric space heating applications are usually figured quite closely. Industrial and commercial users are faced with higher operating costs due to electrical demand charges, and effort is made to keep continuous loads as low as possible, consistent with actual requirements. Excess capacity would require extra means of control to regulate the amount of connected load operating at any one time.

However, due to additional factors involved in industrial heating processes and the intermittent nature of the load, a safety factor in the vicinity of 20% over-capacity is frequently adopted. Depending upon the specific process, factors often are present which cannot be forecast exactly, such as heat losses from exposed surfaces of equipment, heat absorbed by conduction to auxiliary apparatus, etc. Since most processes already include some form of control equipment, these controls serve to limit the kwhr consumption at any one time to that required without penalty.

Infrared Heating

Industrial heating applications employing infrared lamps take advantage of the high percentage of infrared radiation emitted despite their relatively low operating temperature. Installations consist of one or more infrared lampholders wired in sections, panels or strips arranged so as to direct the radiant output of the lamps onto the surface to be heated. Since lampholders will be subject to high temperatures at close spacing for long periods of time, a good grade, one-piece porcelain shell type should be specified for the screw-base lamp of 300 watts or less. Larger lamps having the medium bipost base are usually connected to the branch circuit using braided wire welded to the base posts.

Standard switching and control equipment may be used. Where conveyors are used, interlocked circuits should be provided to disconnect lamps when conveyor stops to avoid extreme concentrations.

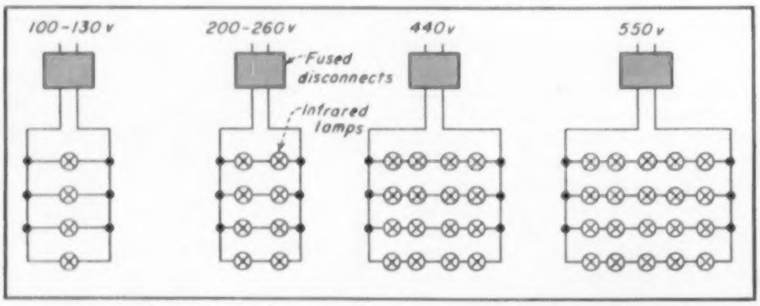
Lamps rated at 115 volts may be used on higher-voltage circuits by connecting several in series to make up the circuit voltage. Lamps are rated at several voltages in the 100-130-volt range to permit selection of voltages which will add up close to the actual circuit voltage and thus permit operation of the lamps at their maximum efficiency. Where series operation is used, the lampholders must be rated for the circuit voltage, not the lamp voltage (National Electrical Code Section 4237).

Although series operation results in lower wiring and equipment costs, the inconvenience of loss of heat from several lamps for each burnout and the subsequent searching for the faulty lamp may make 115-volt circuits (provided through the use of transformers, if necessary) desirable. Maximum rating of branch circuits feeding infrared lamp sections is 50 amps (Sec. 2126c, 4242).

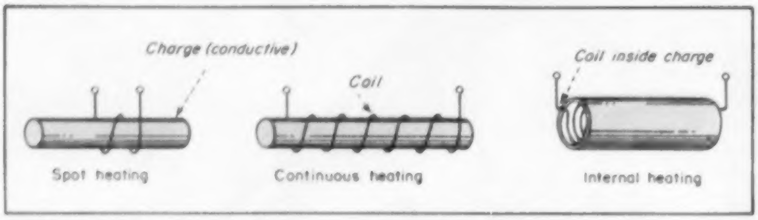
These wiring requirements apply also to tubular quartz lamps, except that all connections are made to branch circuits by splicing to lamp end leads. Lamp wattages vary directly with length of filament and consequently with operating voltage. The 500-watt lamp operates on 115-125 volts, the 1000-watt on 230-450 volts, the 2500-watt on 460-500 volts, and the 5000-watt on 920-1000 volts.

Induction and Dielectric Heating

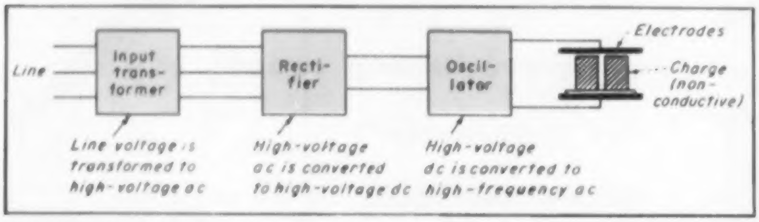
Induction heating equipment uses an alternating magnetic flux



INFRARED LAMPS rated at 115 volts may be connected in series for operation on circuits of higher voltage, provided that lampholders are rated for the circuit voltage.



INDUCTION HEATING depends upon the formation of an alternating magnetic flux to induce eddy currents within an electrically conductive material, or "charge."



DIELECTRIC HEATING uses an ac radio-frequency current to heat non-conducting materials placed between two conducting surfaces.

to induce eddy currents within the mass to be heated. Frequencies of from 60 to several megacycles are used, depending upon economic factors of the generating source and the nature and configuration of the heated material. Apparatus used to produce the desired frequency includes rotating machines (usually a high-cycle generator driven by a 60-cycle motor), spark-gap apparatus, and electric oscillators.

The mass to be heated (charge) requires no terminals to be connected to it, but it must be an electrically conductive material. A coil around the charge is essentially a transformer primary, the induced current in the charge representing a short-circuited secondary and the heat absorbed by the charge the output.

Production layouts and space limitations dictate the location of the power-generating equipment, which is often isolated from the heating apparatus (load applicator). This introduces special problems of transmission of the current from the generator to the applicator, since conductor reactance at high frequencies become a major consideration. Both insulated and uninsulated conductors are used, depending upon conditions under which the installation is to be made, the costs of installing the conductors, and the cost of the required power-factor-correcting capacitors. Bare conductors are usually hollow, of round or square cross-section. Insulated coaxial conductors are often used because of ease of installation; however, their current-carrying capacity is lower than equivalent sized bare conductors. Since transmission of the generator output to the load applicator has such a direct bearing on proper operation of the equipment, details on conductor types and sizes to be used will invariably be specified by the equipment manufacturer.

Dielectric heating is used for non-conducting materials. Heating is accomplished by placing the material between two conducting surfaces carrying an ac radio-frequency current, the entire set-up resembling in its operation a large capacitor. Electronic equipment is used to produce the radio-frequency currents required for operation.

Unlike induction heating apparatus, the high frequency generating source is not remotely located; hence conventional power feeders are used to supply the equipment. Special controls and safeguards required are built in or supplied by the manufacturer.

Code Article 665 contains miscellaneous provisions governing supply conductors, protection, control and grounding of induction and dielectric heating equipment.

Derating of Circuits

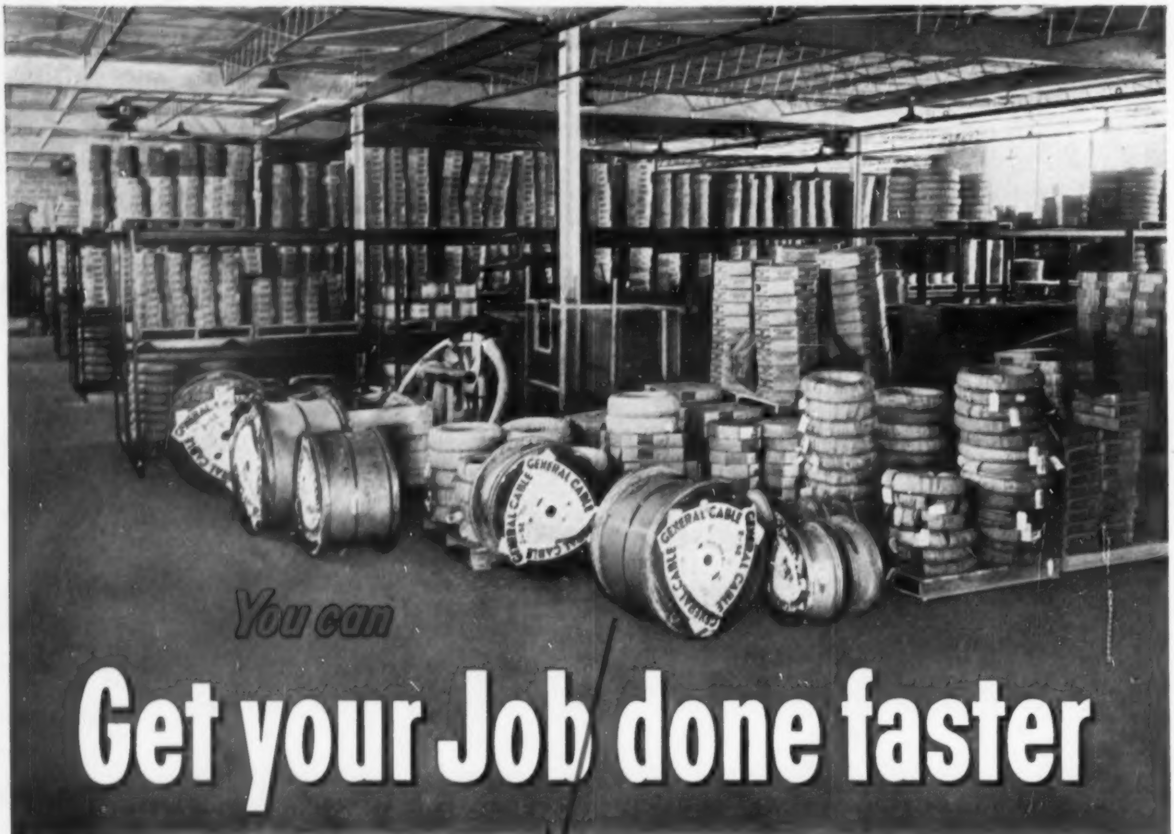
Whereas some specific industrial heating installations are such as to make it impossible to operate all equipment simultaneously, accurate diversity information on the heating load supplied is frequently unavailable. Where such is the case, branch circuits feeding heating equipment are assumed to be carrying a continuous load, and, to compensate for the expected increase in heating effect, the total load must not exceed 80% of the circuit rating (Sec. 2125b).

Feeder loads are computed as 100% of the total connected load on all branch circuits served by the feeder. If, however, an accurate determination can be made of intermittent operation of the heating load which shows that only a definite portion of the load is energized at one time, the code-enforcing authority may permit feeder conductors to be of a capacity less than 100% (Sec. 2203h). From a design standpoint, the 100% figure should be specified unless definite diversified operation makes such a procedure clearly economically unfeasible.

The build-up of ambient heat within the raceway is also aggravated by increasing the number of conductors in the raceway. Thus, where four or more current-carrying conductors occupy the same raceway, both factors contribute to normal operation, and an additional derating factor must be applied in accordance with Notes 4 and 5 of Table 1 of the code.

For example, assume that two 5-kw, single-phase, 240-volt industrial forced-convection type heating units each drawing 21 amps are wired using a common conduit for part of the run from the controllers to the units. Assume also that excessive voltage drop is not involved. Since there will be four current-carrying conductors in this section of the conduit and since a continuous load must be assumed, the branch circuit conductor size required to each unit would be No. 8 (assume Type RH), which may be loaded under these conditions to only $45 \times 0.8 \times 0.8$ or 28.8 amps. No. 10 RH, which would be sufficient for each unit if used in separate conduit runs, must be derated to $30 \times 0.8 \times 0.8$ or 19.2 amps for use in the common conduit.

It is also pertinent to note that branch circuit fuses must be chosen in accordance with the conductor allowable current-carrying capacity and the rating of the appliance (Sec. 2122). While the circuits of the above example would be fused on the basis of the motor starting current, a natural convection heater

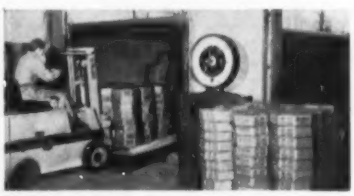


Backing up the stocks carried by your AUTHORIZED GENERAL CABLE DISTRIBUTOR are large stocks at a nearby GENERAL CABLE Distributing Center.

The result . . . everything you need is readily and quickly available. Specify General Cable.

29 "GENERAL" Distributing Centers Coast-to-Coast.

All these stocks in light traffic locations for fast delivery.



General Cable *. . . at your service!*

GENERAL CABLE CORPORATION, 420 Lexington Avenue, New York 17, N.Y. Offices and Distribution Centers Coast-to-Coast

ALLOWABLE MAXIMUM LOADS, COPPER CONDUCTORS

Derated for Heating Circuits**

A. 100%; 30C		X													
B. 80%; continuous load			X			X	X			X	X	X	X	X	X
C. 80%; 4 to 6 conductors				X		X						X		X	
D. 70%; 7 to 9 conductors					X		X						X		X
E. 82%; interior walls; 40C								X		X		X	X		
F. 58%; ceilings; 50C									X		X			X	X
Types	**Size AWG**	**Allowable Maximum Loads (amperes)***													
	14	15	12	12	10.5	9.6	8.4	12.3	8.7	9.8	6.9	7.8	6.8	5.5	4.8
	12	20	16	16	14.0	12.8	11.2	16.4	11.6	13.1	9.2	10.4	9.1	7.4	6.4
Type RH	10	30	24	24	21.0	19.2	16.8	24.6	17.4	19.6	13.9	15.7	13.7	11.1	9.7
	8	45	36	36	31.5	28.8	25.2	36.9	26.1	29.5	20.8	23.6	20.6	16.7	14.6
Type RH-RW in dry locations	6	65	52	52	45.5	41.6	36.4	53.3	37.7	42.6	30.1	34.0	29.8	24.1	21.1
	4	85	68	68	59.5	54.4	47.6	69.7	49.3	55.7	39.4	44.6	39.0	31.5	27.6
	3	100	80	80	70.0	64.0	56.0	82.0	58.0	65.6	46.4	52.4	45.9	37.1	32.4
Type RHW	2	115	92	92	80.5	73.6	64.4	94.3	66.7	75.4	53.3	60.3	52.8	42.6	37.3
	1	130	104	104	91.0	83.2	72.8	106.6	75.4	85.2	60.3	68.2	59.6	48.2	42.2
	0	150	120	120	105.0	96.0	84.0	123.0	87.0	98.4	69.6	78.7	68.8	55.6	48.7
	00	175	140	140	122.5	112.0	98.0	143.5	101.5	114.8	81.2	91.8	80.3	64.9	56.8
	000	200	160	160	140.0	128.0	112.0	164.0	116.0	131.2	92.8	104.9	91.8	74.2	64.9
	0000	230	184	184	161.0	147.2	128.8	188.6	133.4	150.8	106.7	120.7	105.6	85.3	74.7
Type R	14	15	12	12	10.5	9.6	8.4	12.3	8.7	9.8	6.9	7.8	6.8	5.5	4.8
Type RW	12	20	16	16	14.0	12.8	11.2	16.4	11.6	13.1	9.2	10.4	9.1	7.4	6.4
	10	30	24	24	21.0	19.2	16.8	24.6	17.4	19.6	13.9	15.7	13.7	11.1	9.7
Type RU	8	40	32	32	28.0	25.6	22.4	32.8	23.2	26.2	18.5	20.9	18.3	14.8	12.9
Type RUW (Sizes 14 through 2 only)	6	55	44	44	38.5	35.2	30.8	45.1	31.9	36.0	25.5	28.8	25.2	20.4	17.8
	4	70	56	56	49.0	44.8	39.2	57.4	40.6	45.9	32.4	36.7	32.1	25.9	22.7
	3	80	64	64	56.0	51.2	44.8	65.6	46.4	52.4	37.1	41.9	36.7	29.6	25.9
	2	95	76	76	66.5	60.8	53.2	77.9	55.1	62.3	44.0	49.8	43.6	35.2	30.8
Type RH-RW in wet locations	1	110	88	88	77.0	70.4	61.6	90.0	63.8	72.1	51.0	57.7	50.5	40.8	35.7
	0	125	100	100	87.5	80.0	70.0	102.5	72.5	82.0	58.0	65.6	57.4	46.4	40.6
Type T	00	145	116	116	101.5	92.8	81.2	118.9	84.1	95.1	67.2	76.0	66.5	53.8	47.0
	000	165	132	132	115.5	105.6	92.4	135.3	95.7	108.2	76.5	86.5	75.7	61.2	53.5
Type TW	0000	195	156	156	135.5	124.8	109.2	159.9	113.1	127.9	90.4	102.2	89.5	72.3	63.3

*Fractions of an ampere beyond the first decimal place have been dropped.

****Key to Derating Factors** (References are to National Electrical Code, 1953)

A. Normal, not more than 3 conductors in raceway or cable or direct burial, room temperature 30C (Table 1, Chapter X.)

B. Derated to 80% for loads continuing for long periods (Art. 2125b).

C. Derated to 80% for 4 to 6 conductors in raceway or cable (Note 4, Table 1, Chapter X).

D. Derated to 70% for 7 to 9 conductors in raceway or cable (Note 4, Table 1, Chapter X).

E. Derated to 82% for installation in interior walls containing heating equipment; temperature 40C (Art. 4279b).

F. Derated to 58% for installation above ceilings containing heating equipment where conductors are installed within thermal insulation or within joist space containing no thermal insulation; temperature 50C (Art. 4278a and c).

How to Use Table: Locate vertical column at top of page in which applicable derating factors have been checked. Read allowable loads in that column opposite the appropriate wire type and size.

of the same rating under similar conditions would require 30-amp fuses based on 150% of the 21-amp rating.

Where wall or ceiling installations of heating equipment are made, additional derating of circuit conductors may be necessary as provided by Sec. 4278 and 4279. These articles make provision for the added ambient heat within the walls or ceiling due to the proximity of the heating equipment. In general, where conductors are installed within ceiling insulation or above an uninsulated heated ceiling, an ambient temperature of 50C must be assumed, with a consequent derating of capacity in accordance with correction factors of code Table 1. Conductors within heated interior walls must be derated assuming 40C ambient temperature.

For convenience, normal conductor current-carrying capacities have been reduced in accordance with these various requirements and maximum loadings are presented in the accompanying table "Allowable Maximum Load, Copper Conductors."

It is conceivable, then, that the conductors to a heater load for a given application may be subject to three deratings: for continuous load, for reasons of conduit fill, or due to proximity of the heat-producing device. A No. 10 R conductor might thus be reduced to an allowable load of only $30 \times 0.8 \times 0.7 \times 0.58$ or 9.7 amps.

In general, each individual case of this type must be analyzed from the standpoint of conduit costs vs conductor costs, availability of space for conduit runs, required locations of heaters and controllers, etc. Installations should be planned to avoid the extreme derating of conductors.

Voltage Drop

Sec. 2202 requires feeder conductors to be such that voltage drop up to the final distribution point for the computed heating load will be not more than 3%. However, since the heating effect of current through a resistance varies as the square of the current, a 3% reduction from rated voltage results in a considerable reduction in heater output from rated conditions. Efforts should be made to keep the drop below 2%—not to the final distribution point, but to the actual utilization device.

Assume, for example, that a 10-kw, 230-volt, single-phase unit heater rated at 43.5 amps is wired so that the actual voltage at the heater is 223 volts, an overall drop of 3%. Power output under these conditions would be about 9400 watts, a loss of 600 watts.

Unlike heating with fuels, electric heating design does not provide for a large safety factor in equipment capacity. Each time the heater is energized, unless special controls are incorporated, the *entire* heater capacity is put into use. If the capacity is greatly in excess of that actually needed, unnecessarily high current demand and subsequently high demand charges result. Therefore large losses in capacity due to high voltage drop which are not otherwise provided for may result in an undersized installation which may not do the job assigned.

Where such voltage drops are necessary and expected in advance, additional capacity must be installed to make up the loss and bring the actual watts up to those required by heat loss calculations. The following formula indicates the procedure to be used in arriving at the total installed watts required where the actual voltage to be available at the heater is other than rated voltage:

$$\text{watts} = \left(\begin{array}{c}\text{calculated watts}\\ \text{heat loss}\end{array}\right) \times \left(\frac{\text{rated voltage}}{\text{actual voltage}}\right)^2.$$

For the example above, the installed watts should be 10,000 $\times \left(\frac{220}{223}\right)^2$ or 10.65 kw to compensate for the 3% voltage drop. Since such an increase in capacity in a given confined area may be impractical due to type of equipment used or ratings available, maximum attention should be given in the design stage to developing a feeder and branch circuit distribution plan which will minimize power losses due to voltage drop.

Combined Loads

Normally a heating or air conditioning circuit should not be designed to also feed a lighting load. However, there may be occasions, such as the feeding of a single small unit heater in a factory gate house, where it may be expedient or necessary to pick up the heater load on one of the lighting circuits. Such a practice is recognized by the code.

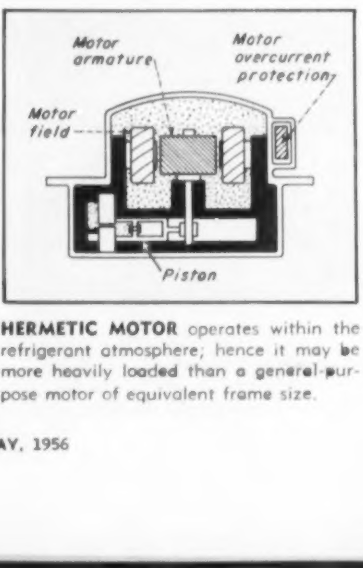
A portable heater incorporating a motor may be rated at any value less than 20×0.8 or 16 amps on such a circuit (Sec. 2125a). If it were rated at 16 amps, there would be no capacity available for the lighting load, and it thus would not be a combined circuit. However, a single motorless portable heater may draw 16 amps (Sec. 2126a), leaving 4 amps for lighting and other smaller appliances.

Fixed heaters and air conditioners may draw no more than 20×0.5 or 10 amps on a circuit combined with lighting loads or portable appliances (Sec. 2126a and 4293). Sec. 4293, by restricting air conditioning loads to 50% of the rating of such circuits, thus establishes air conditioners as fixed appliances. Since both air conditioning and heating loads are considered continuous under the intent of Sec. 2125b, circuit conductors used must be derated to 80%.

In view of the restrictions imposed and the minimum nature of the combined loads permitted, such an arrangement is makeshift at best. Good design should provide individual circuits for heaters and air conditioners.

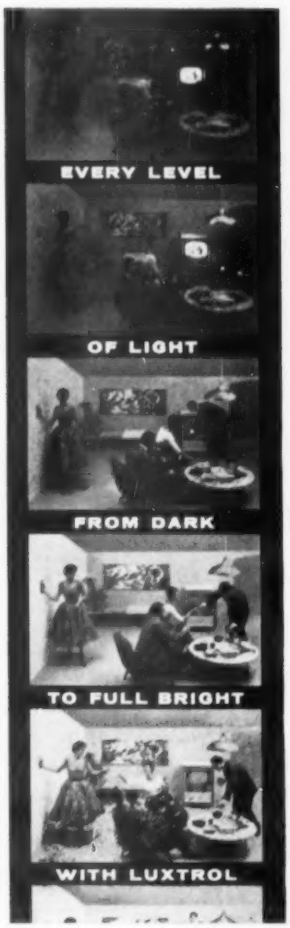
Hermetic Motors

A hermetic motor is one used to drive a refrigerator or air conditioning compressor, both of which are enclosed in the same housing without external shaft or shaft seals, the motor operating in the refrigerant atmosphere. Such motors run somewhat cooler than equivalent motors in open air, since they operate in an ambient tem-



HERMETIC MOTOR operates within the refrigerant atmosphere; hence it may be more heavily loaded than a general-purpose motor of equivalent frame size.

Cash in on this new concept ...controlled light!



All over the country . . . in your own area . . . **the big switch is on!**

The big switch from "all-or-nothing" lighting . . . to all-level LUXTROL Light Control. Yes, that's right! **Any** level at all . . . from dark to full bright. The perfect level of light for every occasion or activity . . . every mood. **And all at the turn of a dial** . . . that is fast replacing the old-fashioned wall switch!

How easy is it to sell LUXTROL? As easy as it is to demonstrate it. As easy as it is to **install** LUXTROL . . . and that's a cinch.

You have no complex wiring. No installation problems at all in installing this soundly engineered, auto-transformer-type unit.

Here's all you do. **1 . . . Lay out your wiring** according to specifications. **2 . . . Attach the box** to either studding or horizontal supports. (It comes with mounting ears on all four sides.) **3 . . .** After the plasterer has been around, **place the control** in the box . . . and put on the face plate.

LUXTROL units are trouble- and service-free! They are built by a leading producer of commercial lighting-control systems. They have both fuse and thermal-overload protection. Operate smoothly, safely, silently. Are approved by Underwriters' Laboratories.

LUXTROL can control all 3 important methods of lighting: incandescent, fluorescent and cold-cathode. See a LUXTROL demonstration. And, meanwhile, send the coupon for complete information. Today.

new

LUXTROL Light Control

A product of The Superior Electric Company

The Superior Electric Company
14056 Demers Avenue, Bristol, Conn.

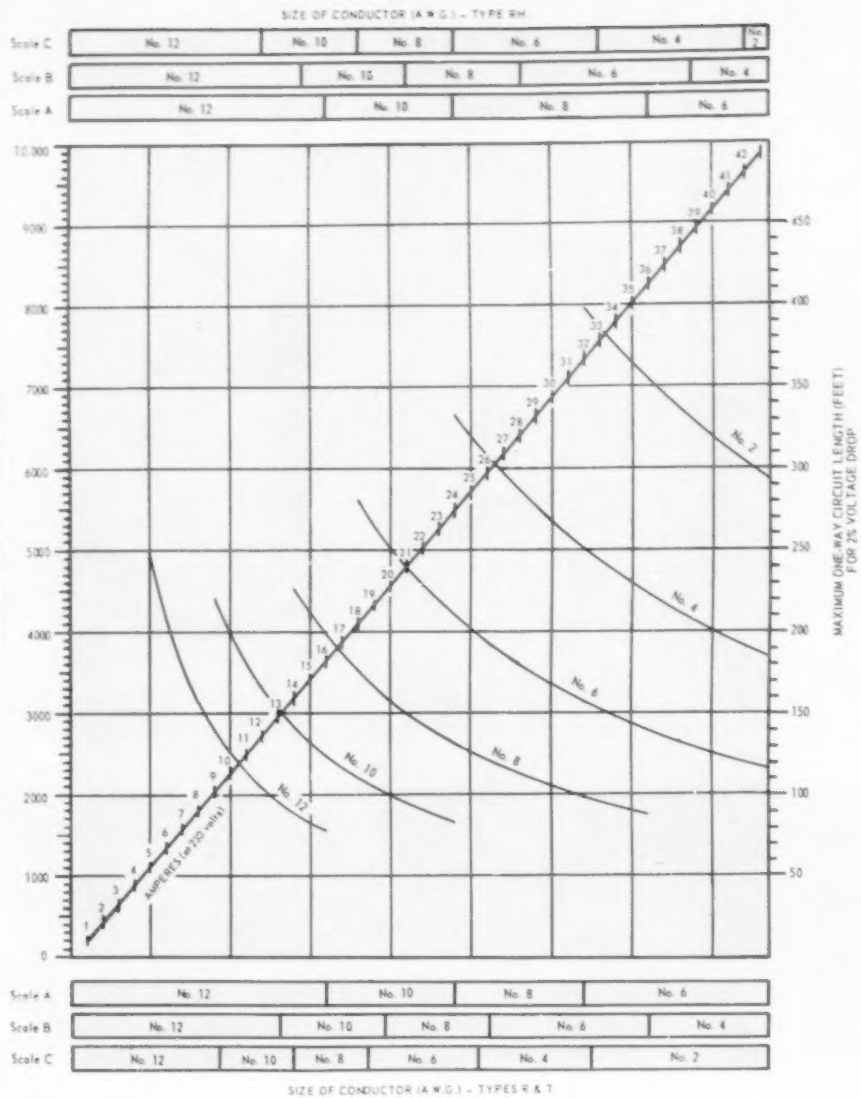
Please send me full design data on new LUXTROL *Light Control.*

Name__________

Street__________

City__________ Zone____ State____

RECOMMENDED WIRE SIZES AND CIRCUIT LENGTHS FOR ELECTRIC SPACE HEATING CIRCUITS



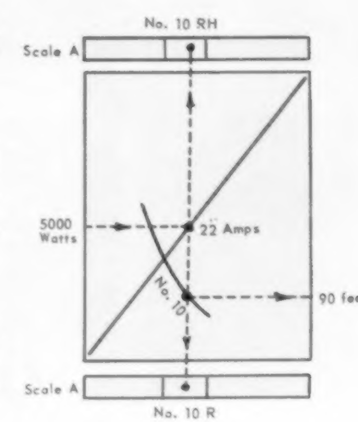
NOTES

1. If more than one heater is used on a circuit, the N.E.C. limits the total load on the circuit to 24 amps, with a 30-amp maximum overcurrent protective device.
2. For wire Types R or T (or equivalent): Use scales A, B or C at bottom of chart.
3. For wire Type RH (or equivalent): Use scales A, B or C at top of chart.
4. Use Scale A: If the wiring is installed either in heated exterior walls outside of the thermal insulation; or above heated ceilings over thermal insulation at least 2 inches thick; or in walls, partitions or ceilings which do not contain heating equipment.
5. Use Scale B: If any part of the wiring is installed in heated interior walls or partitions.
6. Use Scale C: If any part of the wiring is installed above heated ceilings within the thermal insulation, or above heated ceilings having no thermal insulation.
7. Scales A, B and C may also be used to find required sizes of wiring not connected with the heating system but passing through walls or ceilings as described above.
8. In using chart for 115-volt circuits, follow the procedure described below, but begin with a heating load equal to twice the actual load.

HOW TO USE CHART

Assume load is a 5000-watt, 230-volt heater, the wiring to be entirely in outside walls outside the thermal insulation.

1. Locate heating load (5000 watts) on left hand scale. Using straight-edge, move horizontally to diagonal line, which indicates the current (22 amps).
2. To find the Type RH wire size required, move up from the diagonal to Scale A at top of chart and read wire size (No. 10). If Type R or T is to be used, move down from diagonal and read the wire size (also No. 10) on Scale A at bottom of chart. (See note 4 above.)
3. To find the maximum one-way circuit length to avoid more than 2% voltage drop, go down from the diagonal to the curve representing the wire size selected (No. 10), then horizontally to the right-hand scale, which gives the circuit length (90 feet).




make money – make friends
with SMITHCRAFT SCHOOL LIGHTING!
Smithcraft EYE-Q two-light, all-steel, louvered.
Smithcraft FEDERAL two-light all-steel or plastic-sided, louvered.
Smithcraft MERCURY two-, three-, or four-light, all-steel, louvered.
Smithcraft SHERATON two- or four-light plastic-sided, louvered.
Smithcraft CHALKBOARDER designed for chalkboards, bulletin boards, etc.
It's one thing to design fluorescent fixtures for maximum lighting efficiency and appearance . . . It's another to design them so they can be installed quickly and maintained simply! Smithcraft has successfully combined these benefits in the same lighting units, with the result that your Smithcraft school lighting jobs are truly outstanding — and properly profitable! You can depend on Smithcraft for the features that save you — and your customers — time and money!
SMITHCRAFT MEETS THE 6 BASIC REQUIREMENTS OF SCHOOL LIGHTING
• ECONOMY
• EFFICIENCY
• EASE OF INSTALLATION
• EASE OF MAINTENANCE
• APPEARANCE
• SAFETY
Write Today for complete information on Smithcraft School Lighting.
Smithcraft
LIGHTING DIVISION
CHELSEA 50, MASSACHUSETTS
America's finest fluorescent lighting

Cooling Capacity vs Motor Horsepower

Tons of Cooling*	Required Horsepower**
1.5	2.5
2	3.5
2.5	4.5
3	5.4
3.5	6.3
4	7.0
4.5	7.9

*For hermetic compressors rated at 80F, 50% humidity inside; and 95F, 40% humidity outside.

**At maximum load conditions of 95F, 50% humidity inside; and 120F outside, operating at 10% below rated voltage.

perature considerably below that usually encountered. The cooling of the motor is accomplished by the cool returning gases flowing over the winding; thus the horsepower capabilities will be dependent upon the gas temperature, and in turn upon the temperature required in the space to be cooled and the maximum outdoor temperature to be encountered.

As a result, a hermetic motor may be loaded from 170 to 200% higher than a general purpose motor of equivalent frame size using the same amount of iron and copper. Its capabilities cannot be accurately defined in horsepower, and the often-used rule-of-thumb stating "one hp per ton of refrigeration" can lead to serious errors. Air conditioners are usually rated at standard conditions of temperature and humidity; however they must be capable of performing at a high load condition of 95F, 50% humidity inside and 120F outside, at 10% below rated voltage. The above table "Cooling Capacity vs Motor Horsepower" points out the difference between tons of cooling and motor horsepower at such conditions.

Recognizing these differences, the code does not require hermetic motors to be rated in horsepower. Instead, the full-load current (and locked-rotor current for polyphase motors and larger single-phase motors) in amperes must be shown on the nameplate. Therefore the usual method of selecting ratings of motor controllers and disconnects according to the horsepower rating of the motor must be modified for hermetic motors. Similarly, the use of Tables 22 through 24 of the code for obtaining current values for the determination of branch circuit conductor sizes does not apply.

Following are circuit and equipment requirements for hermetic motors as specified by the code:

Branch circuit current-carrying capacity is computed as 125% of the motor nameplate full-load current (Sec. 4312 and 4309b).

Branch circuit overcurrent protection is determined using the motor nameplate full-load current (Sec. 4309b) with Tables 26 and 27 and/or Table 20 as previously outlined for general purpose motors. Air-conditioning loads are considered to be continuous; as such they cannot exceed 80% of the branch circuit rating (Sec. 4293).

Motor running protection, where not provided as an inherent part of the motor, is determined using the nameplate full-load current (Sec. 4309b). The procedure is identical to that previously outlined for general purpose motors, except that where current values thus computed do not correspond exactly to standard ratings of the type of protective device to be used, the next lower rating must be specified (Sec. 4322a-1, 4322c-1, 4324). Since this procedure could result in a slight loss in efficiency, and using the next higher rating would sacrifice safe performance, running protection is almost invariably supplied by the manufacturer. The protector must operate within close limits, hermetic motors being more heavily loaded than a conventional motor of equivalent frame size, and a shorter time interval exists before burnout will occur should locked-rotor conditions be imposed by capacitor failure, open windings, etc.

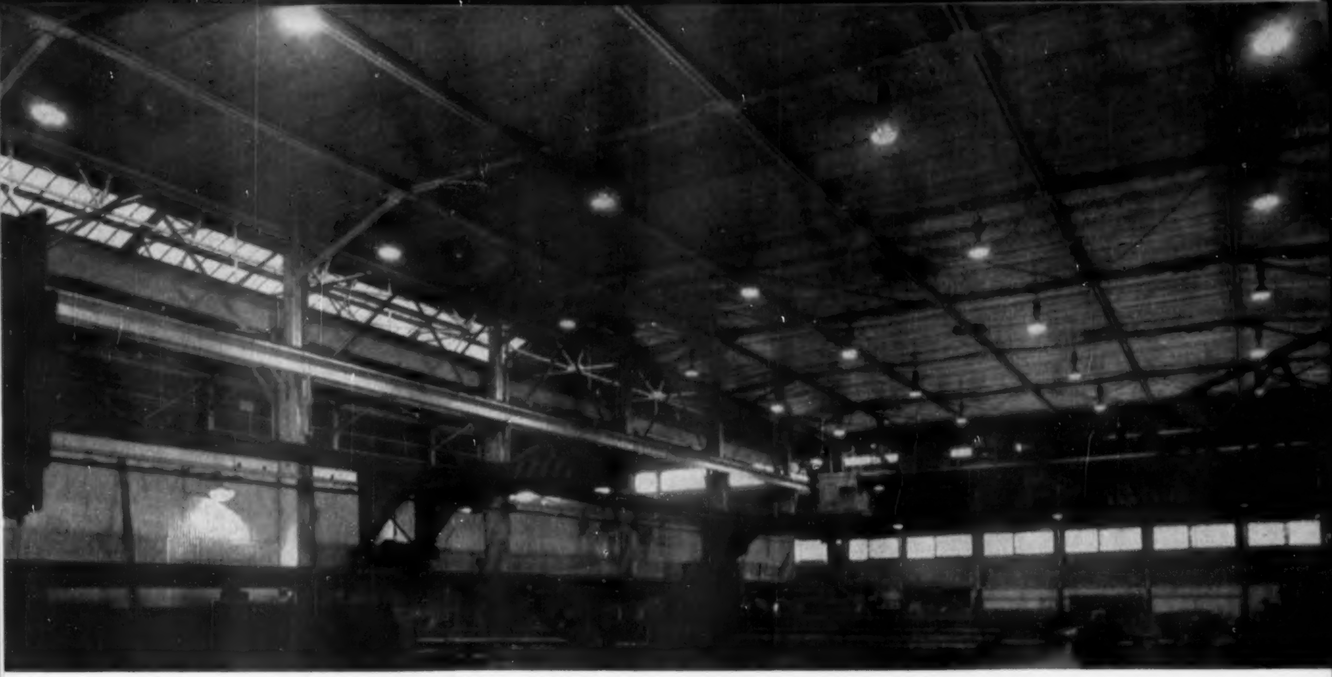
Motor controllers (Sec. 4383e) are normally rated in horsepower; but since hermetic motors are not, the controller size must be selected on the basis of both the motor nameplate full-load current and the locked-rotor current. The size required (in horsepower) is first located in Tables 22, 23 or 24 opposite the motor full-load current. (If the exact current value is not listed, the next higher one is used.) The size (again in horsepower) is then located in Table 25 opposite the locked-rotor current. If the two horsepower ratings thus obtained do not agree, the higher of the two is to be selected.

Some controllers may be rated not in horsepower but in full-load

Code Table 25: Interrupting Capacity of Motor Controller and Disconnecting Means

For use in selecting controller and disconnect for hermetic motors

Max hp Rating	Maximum Interrupting Capacity (amperes)					
	Single Phase			Two or Three Phase		
	115V	230V	110V	220V	440V	550V
½	44.4	22.2	24	12	6	4.8
¾	61.2	30.6	33.6	16.8	8.4	6.6
1	78	39	42	21	10.8	8.4
1½	110.4	55.2	60	30	15	12
2	144	72	78	39	19.8	15.6
3	204	102		54	27	24
5	336	168		90	45	36
7½	480	240		132	66	54
10	600	300		162	84	66
15				240	120	96
20				312	156	126
25				384	192	156
30				468	234	186
40				624	312	246
50				750	378	300
60				900	450	350
75				1110	558	444
100				1476	738	588
125				1860	930	744
150				2160	1080	864
200				2880	1440	1152



400W MERCURY VAPOR LAMP LIFE TEST INSTALLATION: This photograph, taken in a steel service shop of Joseph T. Ryerson & Son Inc., shows Sola Constant Wattage Mercury Vapor Lamp Transformers mounted in a pendant-type, high-bay installation. Ryerson industrial engineers checked this installation continuously to record increased lamp life arising from constant wattage ballast regulation.

Mercury Vapor Lamp Life Increased 50% with Sola Constant Wattage Transformers in Ryerson Test Installation

Getting the most mercury vapor lighting for your dollar demands consideration of factors other than lamp and transformer cost. Quality of illumination, long lamp life, and system reliability are essential for maximum efficiency and economy in mercury vapor lighting systems.

The pilot Sola-ballasted, mercury vapor lighting installation of Joseph T. Ryerson & Son Inc. shows the following advantages of *regulated* mercury vapor lamp operation: Increased lamp life, constant lumen output (often in the face of line voltage variations as great as 25%), reliability, and reduced system maintenance costs. Specifically, the following eight features can be yours when your mercury vapor lamps operate from Sola Constant Wattage Mercury Vapor Lamp Transformers:

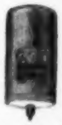
1. *Constant light output within ±2% regardless of line voltage variations as great as 25%.*
2. *Lamps stay lit, even when line voltage drops as much as 40v (on 110v line).*
3. *Positive starting.*
4. *Elimination of primary taps.*
5. *Negligible starting current surge.*
6. *Protection on both open and short circuit.*
7. *Extended lamp life.*
8. *More ballasts can be installed on each circuit.*

These premium performance units are also available in a sealed housing for outdoor, weatherproof, commercial or industrial applications. They are particularly suitable for gasoline stations, plant protection, store fronts and parking lots.

COMPUTING LAMP LIFE: Here a Ryerson industrial engineer reads a service-hour register used to establish lamp life of the above installation. Lamp life is rated at 6,000 hours. At the conclusion of the test — 10,000 hours — 90% of the Sola-ballasted lamps were still operating. This is a lamp life extension of 50%.

Write for Bulletin 17E-MV-211 for Indoor Application data and Bulletin 17E-MV-219 for Outdoor Application data.

SOLA *Mercury Vapor Lamp* **TRANSFORMERS**



Regulated Outdoor

Regulated Indoor

Conventional Indoor

CONSTANT VOLTAGE TRANSFORMERS for Regulation of Electronic and Electrical Equipment • **LIGHTING TRANSFORMERS** for All Types of Fluorescent and Mercury Vapor Lamps. • **SOLA ELECTRIC CO., 4633 West 16th Street, Chicago 50, Illinois, Bishop 2-1414** • *NEW YORK 35: 103 E. 125th St., TRafalgar 6-6464 • PHILADELPHIA: Commercial Trust Bldg., Rittenhouse 6-4988 • BOSTON: 272 Centre Street, Newton 58, Mass., Bigelow 4-3354 • CLEVELAND 15: 1836 Euclid Ave., PRospect 1-6400 • KANSAS CITY 2, MO.: 406 W. 34th St., Jefferson 4382 • LOS ANGELES 23: 3138 E. Olympic Blvd., ANgelus 9-9431 • TORONTO 17, ONTARIO: 102 Laird Drive, Mayfair 4554 • Representatives in Other Principal Cities*

current and locked-rotor current. In such cases, these rated values must be equal to or greater than the nameplate full-load current and locked-rotor current, respectively, of the motor.

Motor disconnect (Sec. 4403b) is selected in the same manner as the controller. Thus the rating of the disconnect should be equal to that of the controller.

EXAMPLE: It is required to design circuit and controls for a 5-hp hermetic compressor containing a 3-phase, 220-volt, squirrel-cage induction motor having nameplate ratings of 25.8 amps full load and 90 amps locked-rotor current.

Branch circuit: Based on nameplate full-load current, carrying capacity of branch circuit conductors would be 25.8 × 1.25 or 32.25 amps, requiring No. 8 conductors (R, RH, T, etc.).

Branch circuit protection: Table 26 specifies for this type of motor a maximum rating of 300% of full-load current. 3 × 25.8 gives 77.4 amps, requiring an 80-amp fuse. Or, Table 20 may be used directly. For full-load current of 26 amps, column 7 of this table show a maximum fuse rating of 80 amps.

Motor running protection, if not provided with the motor, would be rated at 30 amps based on 125% of full-load current of the motor.

Controller and disconnect: In Table 24, a full-load current of 27 amps is the next higher current to the nameplate rating of 25.8, requiring a 10-hp controller and disconnect. For a locked-rotor current of 90 amps, Table 25 requires a 5-hp controller and disconnect. Since the two values do not agree, the higher, or 10 hp, is selected. This selection assures both the controller and disconnect of being able to handle not only the normal running current, but also the maximum current expected in case of locked rotor conditions.

It is pertinent to note that, had the motor been assumed to be 5 hp, use of Table 24 in the usual manner would have given a full-load current value of 15 amps, No. 12 conductors, 45-amp branch circuit fuses, running overcurrent protection of 15 amps, and controller and disconnect rated at 5 hp—inadequate in all respects.

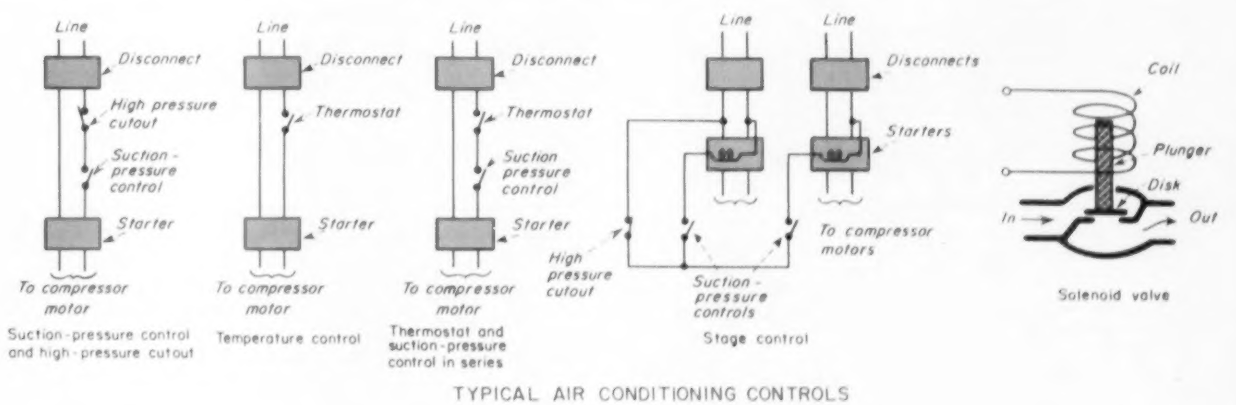
Grounding

The necessity for grounding the cases of window air conditioners frequently raises questions. Applicable code sections are 2545 and 2542. However, Interim Amendment 101, effective Jan. 1, 1955, revised and extended the provisions of these sections to apply to all types of occupancies for all types of equipment. Such equipment is to be grounded

1. If permanently connected to metal-clad wiring
2. If in a wet location and not isolated
3. If within reach of a person standing on the ground outside of a building
4. If in electrical contact with metal or metal lath
5. If operating at more than 150 volts to ground.

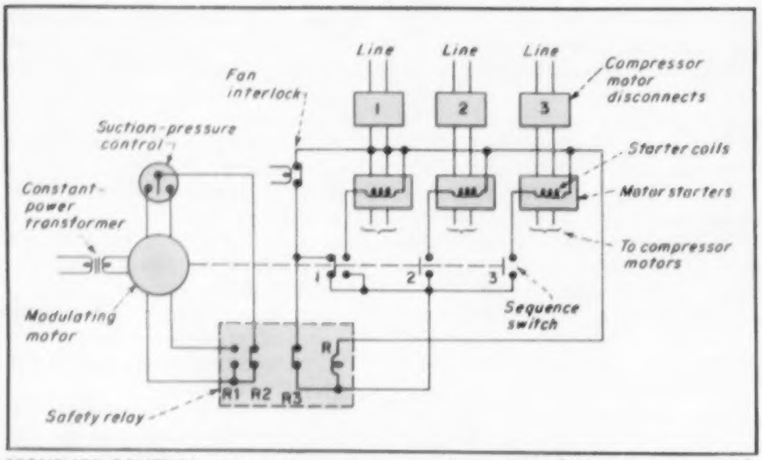
Equipment in hazardous locations is further governed by the provisions of Art. 500.

These are of course minimum requirements. The code recommends that all frames of all portable motors which operate at more than 50 volts and less than 150 volts be grounded where possible. The wisdom of such a practice, extended to air conditioners, is evident. Provision (3) above, for example, requires the casing to be grounded if it is within reach of a person standing on the ground outside the building. From a safety standpoint, a conditioner located within reaching distance of a metal radiator is as much a hazard to an individual as it would be if he were



TYPICAL AIR CONDITIONING CONTROLS

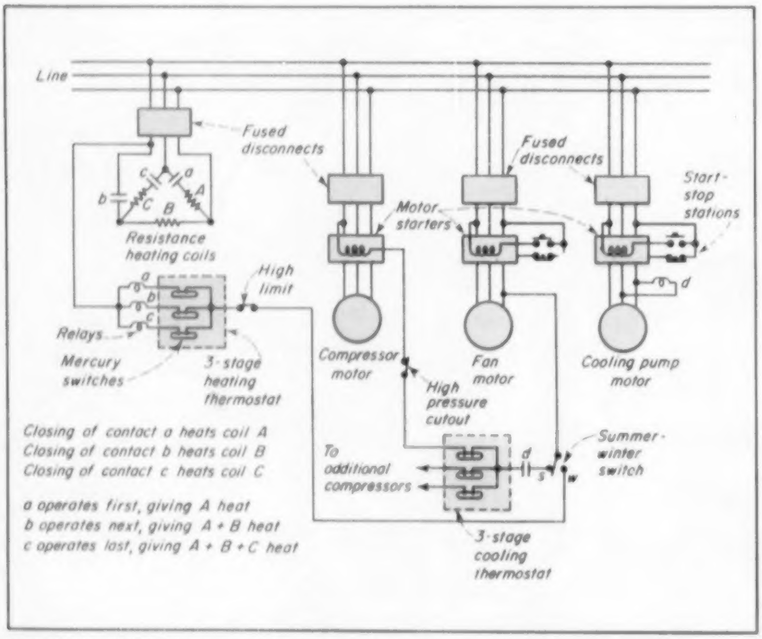
SUCTION PRESSURE CONTROL is a pressure control which closes the circuit to the starter and starts the compressor motor when the suction-line pressure gets above a pre-determined value and stops the motor when the pressure has dropped the correct amount. The control pressure is set to correspond with the evaporator temperature which will provide a particular cooling rate for the existing ambient conditions. **HIGH PRESSURE CUTOUT** is connected to the discharge side (high side) of the compressor. It opens the motor circuit if the pressure rises above a pre-determined value for safe operation. The high-pressure cutout and suction-pressure control are often combined in a single pressure control. **TEMPERATURE CONTROL,** accomplished by a thermostat with or without a remote bulb, is usually used to control the compressor in space air conditioning applications in place of the suction-pressure control, since it can respond more directly to varying cooling requirements. Both controls may be wired in series to provide for automatic defrosting, or the two may be combined in a single unit. **STAGE CONTROL** may be accomplished using two or more suction-pressure controls, the controls being set to bring in the second compressor when cooling requirements exceed the capacity of the first. **SOLENOID VALVE** consists of a magnetic coil and solenoid plunger which controls the seating of a disk between inlet and outlet chambers.



SEQUENCE CONTROL of several compressors is often achieved by using a series of switches operated in sequence by a modulating motor (usually a reversible capacitor motor incorporating some type of balancing relay, energized by a low-voltage constant-power transformer). Safety relay drops out compressors in case of power interruption. When power is resumed, compressors start one at a time in normal sequence.

Normally, safety relay coil R remains energized, and contacts R2 and R3 are closed as shown. A call for greater cooling from suction pressure control energizes motor, causing it to turn slowly in a direction to close sequence switches and start compressors, one at a time, until sufficient cooling capacity has been provided. A drop in requirements rotates motor in opposite direction, opening switches.

Should power fail, relay R drops out contacts R2 and R3, closing contacts R1. This causes motor to rotate until all starter coil circuits are open and switch No. 1 has connected relay coil across line. This puts the relay in a position to reestablish normal control when power returns.



CENTRAL SYSTEM may combine heating and air conditioning equipment controls. Three resistance coils A, B and C, balanced on 3-phase line, are controlled by multi-stage thermostats employing mercury switches and relay coils a, b and c. Relay contacts a, b and c are arranged to permit one, two or all three resistance heating coils to be connected, depending upon amount of heat called for by one or more of the three thermostat settings. A manual summer-winter switch is provided to permit operation of either heating or air conditioning equipment. With this switch set for winter operation, heater relay coils are energized only when fan motor is operating, preventing overheating and subsequent burnouts due to lack of air circulation. Similarly, with S-W switch thrown to summer operation, compressor contactor coils can be energized only by relay d through contacts d when both the fan and cooling water pump are operating.

standing outside on the ground and were able to touch the conditioner. The common use of metal ladders plus the added hazard of falling makes grounding of second-floor units just as important as those on the first floor.

Good design, then, should recognize the intent of grounding practices and incorporate grounding of all conditioner casings whether or not they fall within the narrow code categories itemized above.

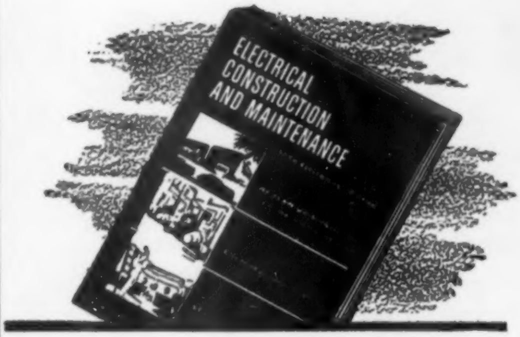
Control

Heating and air conditioning equipment is normally controlled by one or more thermostats operating at line voltage or at reduced voltage through a relay. The thermostat elements used include simple bi-metallic contacts, a bi-metallic contact device operating a mercury switch, or vapor-filled bellows operating a mercury switch. Two or more such elements may be incorporated within a single instrument for multi-stage control, the differential between stages being either permanently set or adjustable. Usual differential between on and off positions ranges from 0.2 to 2 degrees F, 1½ degrees usually being satisfactory for a majority of space heating and cooling installations.

In general, low-voltage thermostats are used when the heating task is more critical, the low-voltage type being capable of more precise limits. However, this factor must be weighed against the economy of the installation, such units being the more expensive.

Good thermostats are being designed today to cycle rather rapidly; that is, the time of each "on" and "off" cycle is short, to prevent excessive swings in room temperature. Some thermostats contain features permitting night set-back of temperature or are used in conjunction with time switches for this purpose; however, there is strong feeling that with well insulated buildings there is little economy in such measures from the standpoint of fuel savings because of thermal storage by the structure and the make-up heat required in the morning. Utilities discourage the practice, since the make-up periods usually correspond to their heavy morning peak period and impose additional burdens on their systems.

To prevent undesirable time lag



ATTENTION: NON-SUBSCRIBERS*

***If you are already a subscriber, this is not a renewal notice. Please pass this card along to some other Electrical Contractor or Industrial Chief Electrician, whom you feel would profit by reading and using this monthly estimating, wiring, installation and maintenance help!**

*Thirteen Valuable Issues Each Year

ELECTRICAL CONTRACTORS: Worried about where to get new business? Want more profitable electrical jobs? Looking for ways to estimate wiring and installation jobs more closely?

. . . Then put ELECTRICAL CONSTRUCTION and MAINTENANCE to work for you! Each month you'll read what other electrical contractors are doing to increase their profits with better estimating and wiring methods . . . and how you can apply these money-making ideas to your business!

You get such down-to-earth help as —

- How to figure added costs of wiring jobs dragging past contract time.
- How to analyze your overhead to cut costs.
- How to quickly take-off material requirements.
- What 14 factors besides labor and material affect your job costs.

INDUSTRIAL CHIEF ELECTRICIANS: Are you looking for ways to cut plant electrical costs? Would you like practical ideas for preventing service breakdowns?

Can you use time-saving shortcuts for plant electrical maintenance?—More accurate electrical estimating?—Save time on your electrical motor repair?

. . . You get all these and more in the 12 other issues of ELECTRICAL CONSTRUCTION and MAINTENANCE! For example you can cash-in on money-saving methods like these:

- How to figure incidental labor and direct job costs . . .
- How to select industrial controls . . .
- How to get better results from motors, transformers and generators . . .
- Plus dozens of practical electrical shortcuts to slash your costs!

Whether you are an electrical contractor or industrial plant chief electrician, you'll find, just as over 32,500 other electrical men have, you can rely on ELECTRICAL CONSTRUCTION and MAINTENANCE for help on how to do better electrical estimating, wiring, installation and maintenance at less cost!

Start ELECTRICAL CONSTRUCTION and MAINTENANCE working for you today! To enter your personal subscription just complete and mail the card below! SUBSCRIBE NOW!

Electrical Construction and Maintenance — May — 1956

YES, SIR! I want to know the latest electrical estimating, wiring and maintenance methods! Enter my subscription to ELECTRICAL CONSTRUCTION and MAINTENANCE for a full year's service (13 helpful issues) for only $3.

☐ Check here for two years only $4

Name ______

Title or Position ______

Address Home ☐ Company ☐ ______

City ______ Zone ______

State ______

Company Name ______

Nature of Business ______

I am in charge of electrical work ☐ Yes ☐ No

Person in charge of electrical work is ______

Operate a motor repair shop?

☐ Yes No ☐

SEND NO MONEY NOW

Mail card today—We'll bill you later.

Please do not write in this box.
C-

5-56

YES, SIR! I want to know the latest electrical estimating, wiring and maintenance methods! Enter my subscription to ELECTRICAL CONSTRUCTION and MAINTENANCE for a full year's service (13 helpful issues) for only $3.

☐ Check here for two years only $4

Name ______

Title or Position ______

Address Home ☐ Company ☐ ______

City ______ Zone ______

State ______

Company Name ______

Nature of Business ______

I am in charge of electrical work ☐ Yes ☐ No

Person in charge of electrical work is ______

Operate a motor repair shop?

☐ Yes No ☐

SEND NO MONEY NOW

Mail card today—We'll bill you later.

Please do not write in this box.
C-

5-56

Estimating Help You Can Rely On —

If you are an electrical contractor, landing a wiring or installation job is one thing — but completing it at a profit is another. If you bid too high, you don't get the job—bid too low and you get the job but lose your shirt in the bargain!

If you are an industrial plant chief electrician, you're faced with many of the same electrical estimating problems as the contractor in order to submit an accurate budget to your boss . . . and check on your costs.

. . . So why take unnecessary chances when you can get your own personal copy of ELECTRICAL CONSTRUCTION and MAINTENANCE each month . . . and have sure-fire, step-by-step electrical estimating and wiring help at your finger-tips!

ELECTRICAL CONSTRUCTION AND MAINTENANCE is written for active, hard-hitting men like you. It brings you the actual experiences of electrical men who are beating the problems of wiring, estimating, code interpretation, lighting layout, maintenance and motor repair.

NOW — 13 issues each Year!

As part of the regular subscription service, ELECTRICAL CONSTRUCTION and MAINTENANCE now publishes in Mid-September the big NEW "ELECTRICAL PRODUCTS GUIDE" issue. The "EPG" is your year 'round guide to "who-makes-what" and "where-to-buy" product information. It's the only complete . . . and completely verified . . . reference on electrical apparatus and supplies, utilization equipment, tools and accessories!

"Questions on the Code" each month . . .

A special feature of ELECTRICAL CONSTRUCTION and MAINTENANCE each month is the "Questions on the National Electrical Code". Here new requirements are explained and analyzed. You're shown how to comply with every specification yet keep your costs and working time to a minimum. Whether you're an electrical contractor, or chief electrician of a plant this code information alone is worth more than the subscription price!

Send no money now—we'll bill you later

Just complete and mail the subscription card below. We'll send a statement later for the small subscription fee—only $3 for a full year's service (13 big, helpful issues), or $4 for two years.

ENTER YOUR SUBSCRIPTION TODAY!

Electrical Construction and Maintenance • May • 1956

—TEAR ALONG LINES—

No Postage Stamp Necessary if Mailed in the United States

BUSINESS REPLY CARD

FIRST CLASS PERMIT NO. 64. NEW YORK, N. Y.

4¢ POSTAGE WILL BE PAID BY –

McGRAW-HILL PUBLISHING CO., INC.

ELECTRICAL CONSTRUCTION & MAINTENANCE

330 WEST 42ND STREET

NEW YORK 36, N. Y.

Postage Will be Paid by McGraw-Hill Pub. Co.

No Postage Stamp Necessary if Mailed in the United States

BUSINESS REPLY CARD

FIRST CLASS PERMIT NO. 64. NEW YORK, N. Y.

4¢ POSTAGE WILL BE PAID BY –

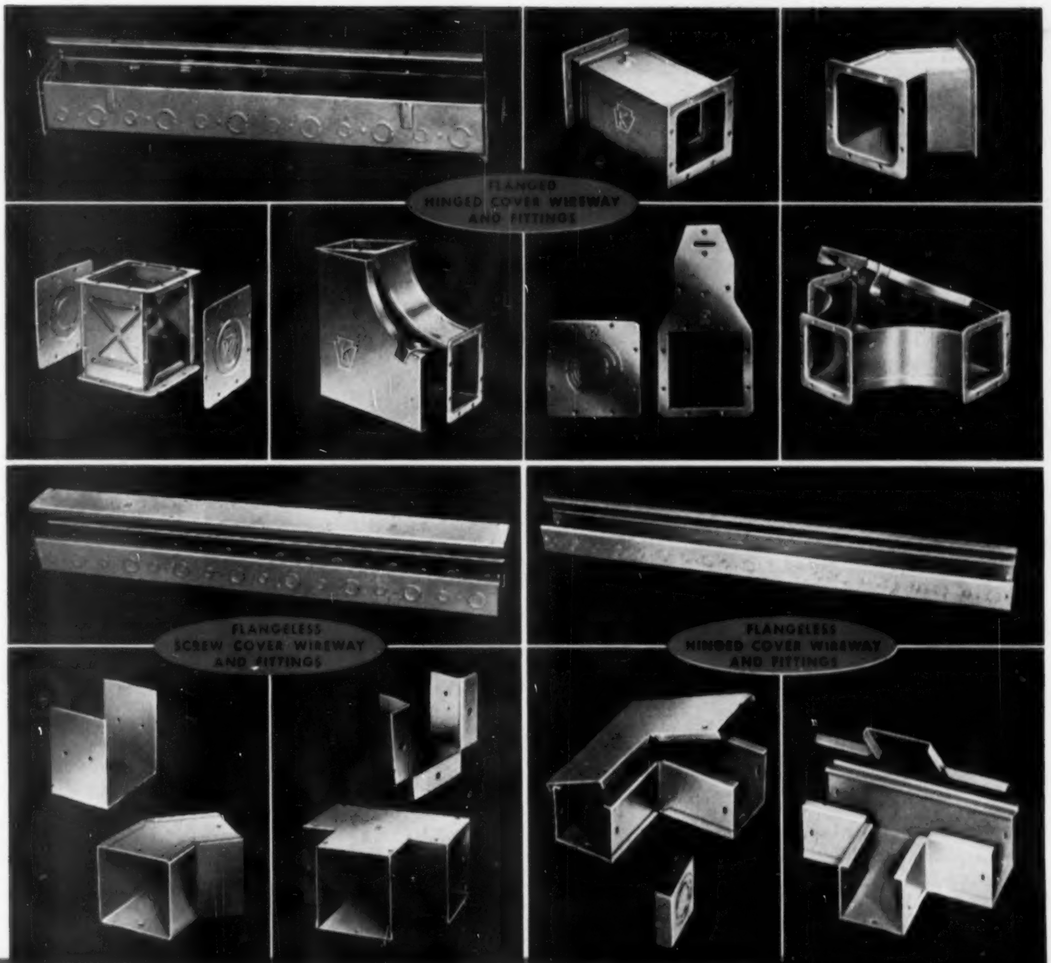
McGRAW-HILL PUBLISHING CO., INC.

ELECTRICAL CONSTRUCTION & MAINTENANCE

330 WEST 42ND STREET

NEW YORK 36, N. Y.

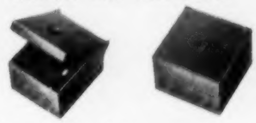
Postage Will be Paid by McGraw-Hill Pub. Co.

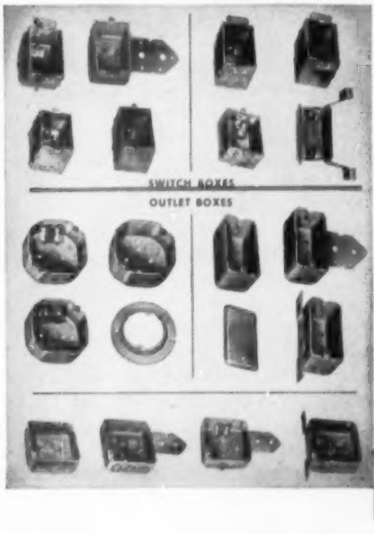


FOR BETTER JOBS AND EXTRA PROFITS, SPECIFY THE

KEYSTONE QUALITY LINE

CABINETS AND PULL BOXES





No doubt about it! When it comes to wiring installation jobs, you can get *what* you want *when* you want it from the Keystone Quality Line. Wireways, for example, are available in both flanged and flangeless styles . . . with hinged or screw covers . . . with or without knockouts . . . and in sizes ranging from 2½" x 2½" x 1' through 8" x 8" x 5'. There's a wide selection of auxiliary fittings to choose from, too, plus cutout boxes and pull boxes in more than 50 different stock sizes . . . and a variety of telephone and current transformer cabinets to meet your exact requirements. And if it's outlet boxes or switch boxes you're looking for, you'll find that Keystone has them . . . in almost every type and size, with proper covers, too. What's more, every item in the Keystone Line is quality-built, priced right, and stocked for immediate shipment direct from factory warehouses! Want more information? Send for your free copy of the new illustrated Keystone catalog today!

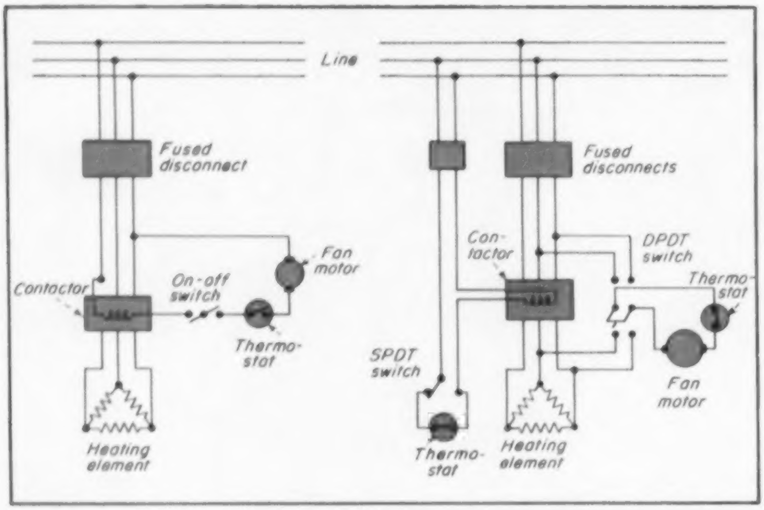
It pays to figure on Keystone

KEYSTONE MANUFACTURING COMPANY

23328 SHERWOOD AVENUE • CENTER LINE (Detroit) MICHIGAN

. . . the Complete Line of Wiring Installation Equipment

SOLD ONLY THROUGH RECOGNIZED ELECTRICAL DISTRIBUTORS



UNIT HEATERS may be controlled by simple on-off switch and thermostat in fan motor circuit (left), both of which must be closed to operate contactor and energize heating element; or separate fused control circuit may be used (right). Summer-winter DPDT switch permits fan to be used independently of heating elements for summer air circulation. Separate single-phase control of contactor coil includes SPDT switch which may be used for manual control of heating element in place of thermostat. An additional thermostat may be inserted in fan motor circuit as shown to enable fan to dissipate heat remaining after heating element has been deenergized. Such a thermostat may also be set to start the fan motor only after the heating element has come up to temperature, avoiding circulation of cool air. For summer operation, this thermostat may be set so as to remain closed continuously, or a short-circuiting switch may be provided.

between a drop in temperature and operation of the thermostat, many instruments make use of internally generated heat or have built-in heaters to cause the contacts to close sooner. Other systems employ an additional outdoor thermostat which is capable of controlling the indoor temperature in accordance with outdoor temperature changes. This principle, called "anticipation," allows the heating system to respond more closely to changes in weather conditions without the normal delay due to thermal storage properties of the building materials.

For central systems using rather large resistor banks, means are usually provided to permit individual elements to be energized one at a time in accordance with the demand for heat. This requires several thermostats, each set to close at successively lower temperatures, or multi-stage instruments containing several operating elements within one enclosure. This eliminates high inrush currents each time heat is called for and makes it unnecessary to energize the entire heating capacity when only a small amount of heat is required. Similar arrangements are made to control individual compressors of multi-stage air conditioning installations. (Since compressor efficiency is considerably reduced at partial loads, central systems usually encountered employ two or more smaller compressors rather than one of large capacity.)

Control Layout

The flexibility of electric heat is one of its big advantages; therefor it should not be hampered by inadequate control. Thermostats should be provided in each individual space to be heated, together with a disconnect switch to make the system inoperative when the space is unoccupied. Thermostats are available containing an OFF position which disconnects both sides of the line and capable of interrupting operating currents. Approved instruments of this type are permitted by the code to serve as both the control and the disconnect (Sec. 4241 and Official Interpretation 428). Local control (other than by regulation of heated air) is more difficult in the case of central systems, except where individual heating elements are located at air outlet registers rather than in a centrally located heating unit.

Local control of air conditioning equipment may be accomplished where individual room units are used; however central system control must be handled through control of the conditioned air rather than through control of compressor cycles.

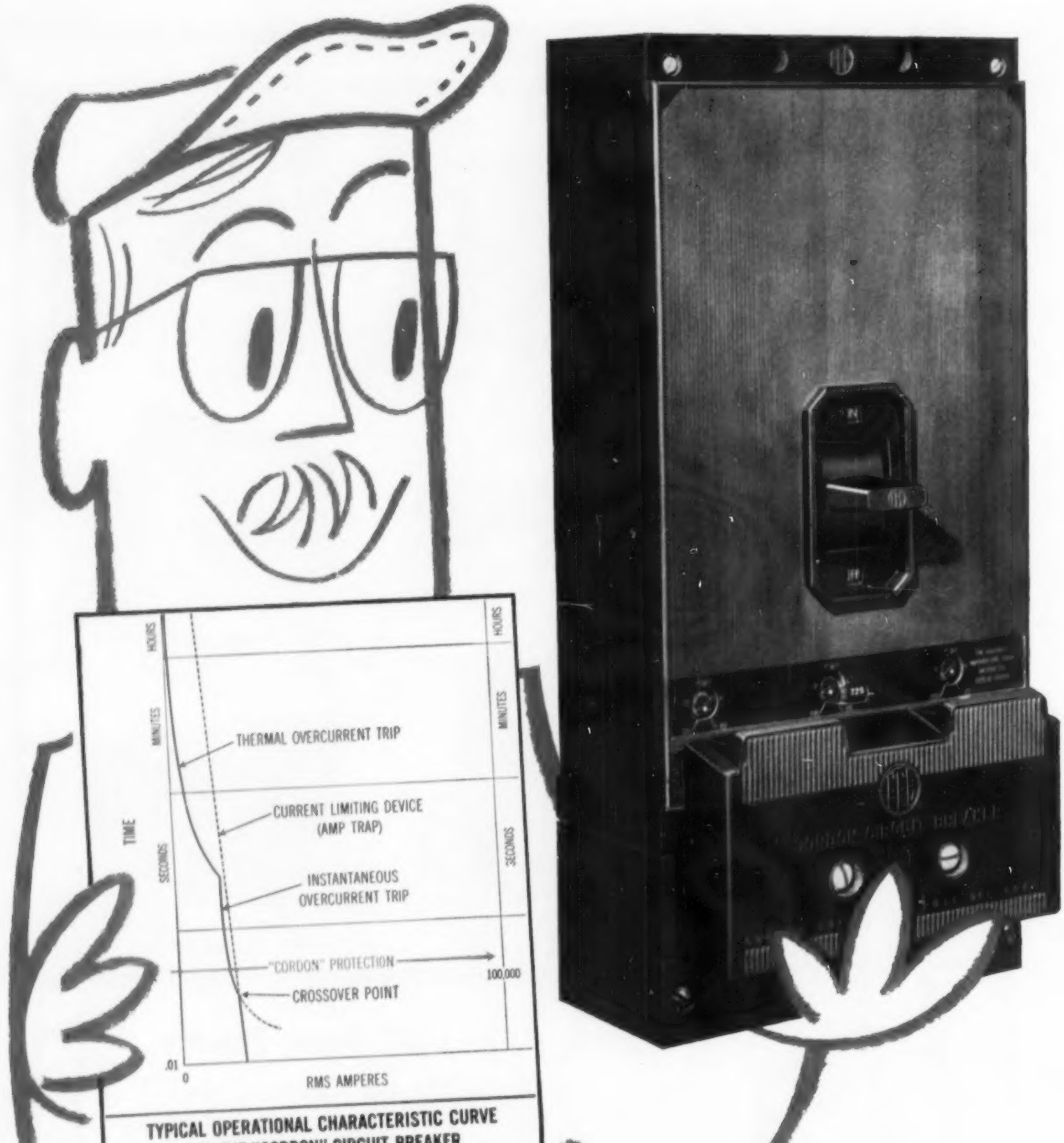
Where several heaters may be operated by a single thermostat, a time-delay feature may be desirable to bring in the units one at a time. This is true even in relatively small installations using certain panel heaters which may draw up to 50% more current when cold than when up to full heat.

Automatic load regulators, although used to a lesser extent today than in the past, may be required by some utilities to limit the maximum demand of a system incorporating electric heat. This is done by transferring the heating equipment from 240 volts to 120 volts, thus reducing the load by 75%. This is usually accomplished by a relay set to operate when a predetermined current is reached by either the heating load, the load other than heating, or the combined load. The heaters are reconnected to 240 volts by a timing device after a specified elapsed time, the transfer being repeated if the demand is still excessive.

Accompanying diagrams show typical circuits employing miscellaneous heating and air conditioning controls likely to be encountered. In general, disconnect switches, motor starters, contactors, etc. are identical to those used for general applications. Contactors frequently employ auxiliary contacts for the purpose of interlocking one motor with another. A typical example is a heat pump installation, the motors being interlocked to prevent the compressor motor from being started unless the well pump and circulating pump motors are operating.

Conversion from summer cooling to winter heating or vice versa is usually accomplished with a double-throw switch. In a water-to-air heat pump, such a switch controls solenoid valves which reverse water-to-refrigerant heat transfer.

Line-voltage circuits are subject to the same general wiring requirements previously discussed; special provisions of the code affecting remote-control and low-voltage circuits are found in Art. 725.



TYPICAL OPERATIONAL CHARACTERISTIC CURVE FOR THE "CORDON" CIRCUIT BREAKER

HOW IT WORKS: Combining and coordinating standard circuit breaker characteristics with specially designed current limiting Amp-traps, the "Cordon" circuit breaker achieves the characteristics shown above.

The thermal-magnetic overcurrent devices provide coordinated protection against overloads and short circuits up to a predetermined value (crossover point). At this point the current limiting Amp-traps assume the fault-clearing duty and extend short circuit protection to 100,000 rms amperes.

Unless the magnitude of a short circuit reaches the crossover point, the Amp-traps are unaffected, and the standard circuit breaker overcurrent devices perform their normal function. Since the fast clearing time of the Amp-trap (less than ½ cycle) provides current limiting, the magnetic and thermal stresses, which are proportional to the square of the current, are greatly reduced. Consequently, the standard molded case type circuit breaker safely withstands the heavy fault current. It is unnecessary to design bus-supporting members or current-carrying parts to meet the maximum peak current.

The Amp-traps are mounted in a molded housing which plugs into the load side of the breaker, forming one compact unit. A design feature of the "Cordon" circuit breaker actuates a common tripper bar when any Amp-trap blows, opening all poles of the circuit breaker. Until the blown Amp-trap is replaced the circuit breaker cannot be closed. A mechanical linkage arrangement automatically opens the circuit breaker before the Amp-trap housing is removed.

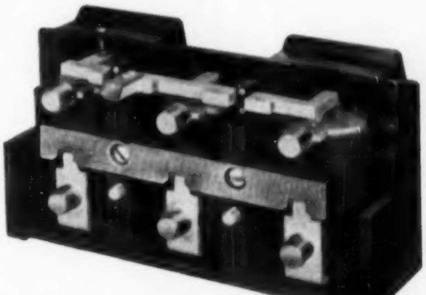
New I-T-E "CORDON" Circuit Breaker

100,000 amp interrupting rating in molded case circuit breakers

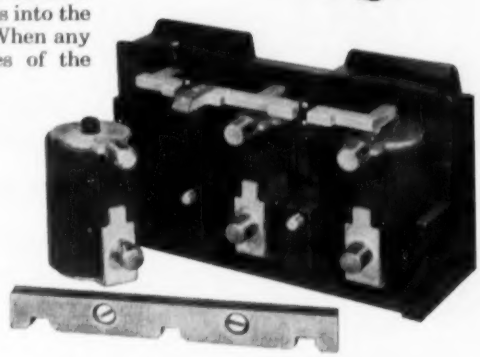
Now—one compact circuit breaker provides the practical, economical solution to meet constantly increasing interrupting requirements. The new "Cordon" circuit breaker provides all of the design and operating advantages of the famed I-T-E molded case breaker, plus interrupting ability up to 100,000 rms amperes.

The "Cordon" circuit breaker can be utilized in normal branch and feeder circuit applications in switchboards, panelboards, load centers, and individual enclosures. Plug-in mounting, rear connected studs, or front connected terminal mounting arrangements are optional.

"Cordon" circuit breakers are available with 2 or 3-pole construction in 100, 225, 400 and 600 ampere frame sizes, 250 v d-c and 600 v a-c. Write for complete details or call your nearest I-T-E office. I-T-E Circuit Breaker Company, Small Air Circuit Breaker Division, 19th & Hamilton Sts., Phila. 30, Pa.



The Amp-traps are mounted in a molded housing which plugs into the load side of the breaker. When any Amp-trap blows, all poles of the breaker are opened.



Draw-out design feature of Amp-trap housing provides accessibility to simplify change of Amp-trap. Amp-trap stud design assures proper alignment and positive connection when inserted in the breaker frame.

To replace a blown Amp-trap (indicated by released plunger), simply loosen two screws, remove the retaining bar, withdraw the blown unit, insert the new one, and replace the retaining bar.

I-T-E CIRCUIT BREAKER COMPANY

Small Air Circuit Breaker Division


B-M
INDENTER TYPE FITTINGS
FOR E.M.T.
Concrete-tight
Briegel, the Original Indenter Fittings are neater in appearance, easier and faster to use. Installation is simple and less expensive. Two quick squeezes sets them forever. Try B-M Indenter Fittings and get more profits from each job.
Red Throat
Insulated Connector
Red Throat
Cross section
All B-M Indenter Fittings are U.L. Approved as concrete-tight and for general use (File Card E10863). Also comply With Federal Specifications W-F-406.
TELESCOPE BM SYSTEM
BRIEGEL METHOD TOOL CO.
GALVA • ILLINOIS
Warehouse Stocks in Principal Cities for Immediate Delivery!

Advertisers' Product Index

ELECTRICAL CONSTRUCTION & MAINTENANCE • MAY, 1956

The listings under major product headings are of manufacturers advertising those products in this issue in sufficient detail to be of value to specifiers or users of those products.

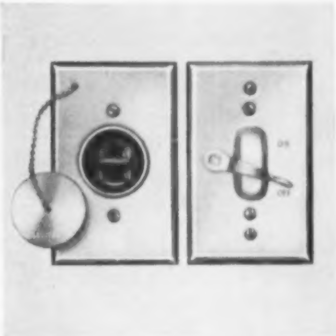
Continued on page 210

Continued From Page 209

Continued on page 212

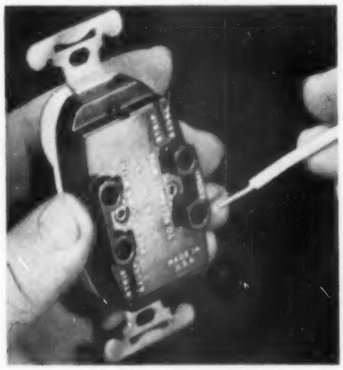
NEW PRODUCTS

Demand for Weatherproof Devices on Increase



Today's trend toward outdoor living is causing an increased demand for weatherproof wiring devices. Therefore, Leviton has added a number of new weatherproof items to its line. These include single pole switches, and 3-way switches, single and duplex outlets with parallel blades, U-ground outlets, and 3-wire "crow's foot" outlets. Receptacles are available either with threaded metal covers or "spring-shut" hinged covers. Furnished with plate and heavy rubber gasket — proved protection for all-weather installations. Listed by U. L.

Leviton Expands Quickwire Series



T-slotted duplex receptacles, and single and duplex receptacles on covers are now a part of the growing line of QUICKWIRE devices. These "spring type", screwless terminal receptacles and switches make installation quick and easy. No screws to loosen and tighten, wire is stripped and inserted into hole. Permanent contact is assured by the exclusive Leviton coil spring connector. All QUICKWIRE items meet U. L. and C. S. A. specifications.

For complete information write Leviton Manufacturing Company, Brooklyn 22, New York.

Continued from page 210

Insulating Materials, Varnishes Tapes, etc.

Lighting Equipment and Lamps

Lighting, Outdoor

Continued on page 214

Continued from page 212

Continued on page 216

4 points about HAZACORD
...that every cord buyer should know

1. what makes Hazacord so flexible?

Every Hazacord conductor is made of a large number of fine-gauge, soft-annealed copper wires. Flexibility is further improved by using a very short lay-up of the strands. Beyond this, all elements of the cord are "lubricated" to work or slip within the compact cord assembly.

2. what's so special about the insulation?

Performite is a tough, resilient insulation that provides an unusually high factor of safety against heat and moisture. This insulation consistently rates better than ASTM requirements in all tests—sometimes as much as 10 times better!

3. what's the purpose of fillers?

They fill out the construction, protecting the insulation from damage by crushing, and give additional longitudinal strength for pulling or suspension. In Hazacord, these fillers *completely* fill in the area between conductors without lessening flexibility.

4. how tough is the outer sheath?

Tough as a truck tire—and for the same reason: mold-curing of a properly designed compound. Every foot of the specially-compounded Hazaprene ZBF Sheath is cured in a metal mold. Result: a protective sheath that's tough enough to take just about any kind of treatment in service.

3398

Complete information in Bulletin H-451. Hazard Insulated Wire Works, Division of The Okonite Company, Passaic, New Jersey.

HAZACORD mold-cured PORTABLE CABLES

PRODUCT OF OKONITE RESEARCH

Continued from page 214

Continued on page 217

Continued from page 216

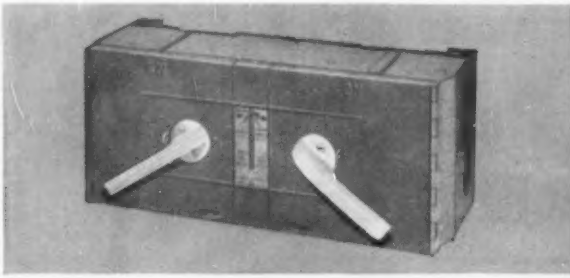
Continued on page 218

Continued from page 217

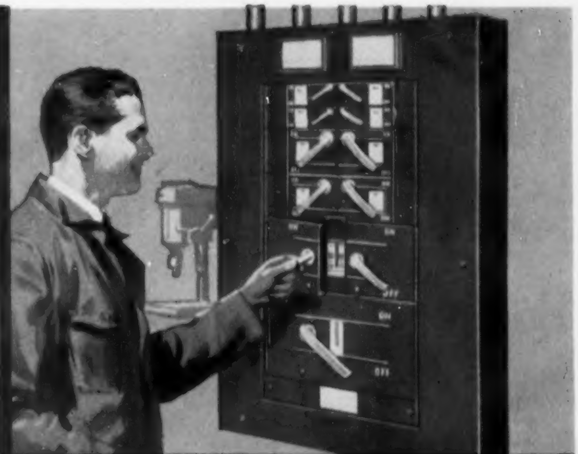
Continued on page 220


greatest convenience feature in range hood history
Air King
exclusive
front view
push button
control
of light and fan
Air King
"PUSH-A-MATIC"
ventilating range hoods
Built-in 3-speed fan control.
Graceful, extra depth design
fits all cabinet depths, choice of
beautiful "Kitchen Matching" finishes.
"BF" SERIES
Specially designed for use in bathrooms.
"TC" SERIES
Vertical Discharge Fans including Roof Jack model.
"KF" SERIES
Pull chain or full automatic sidewall models.
"TB" SERIES
Twin Blower models for Ceiling or Cabinet Installation.
"WF" SERIES
Wall switch or pull chain models for sidewall use.
"CF" SERIES
For ceiling or sidewall mounting.
THESE MODELS ALSO FOR VENTILATING RANGE HOOD USE.
write for fully illustrated catalog folder
BERNS MANUFACTURING CORPORATION
3050 NORTH ROCKWELL STREET CHICAGO 18, ILLINOIS

Continued from page 218



STANDARDIZED, INTERCHANGEABLE SWITCH UNITS permit you to assemble, install, extend or convert the BullDog Power Panel with just two tools—a screwdriver and crescent wrench. Vacu-Break makes switching completely safe. Fused switch units available from 30 to 600 amperes.



BullDog Power Panels Provide

VACU-BREAK ARC CONTROL

For Safe, Sure Operation

Prefabricated . . . trouble-free installation . . . no costly maintenance!

BullDog-engineered equipment continues to set standards! And BullDog Vacu-Break® Power Panels are no exception. Here's an efficient, economical way to centralize lighting and power distribution . . . provide convenient service-entrance equipment, too.

Standardized, interchangeable Type "A" switch units feature exclusive Vacu-Break arc control, plus Clampmatic® action for bolt-tight connections. Maintenance is virtually eliminated—you switch with greater security!

Prefabricated and built under strict quality controls, BullDog Power Panels are easy to assemble. The wiring gutter space is ample to permit positive and speedy installations.

Consult your BullDog field engineer or qualified distributor or write BullDog Electric Products Co., Detroit 32, Mich. © BEPCO

IF IT'S NEW . . . IF IT'S DIFFERENT . . . IF IT'S BETTER . . . IT'S **BULLDOG**

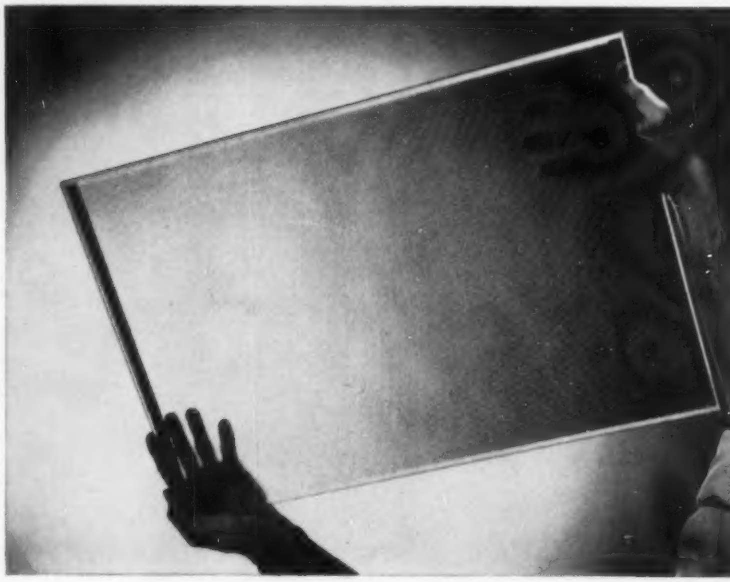
ELECTRIC PRODUCTS COMPANY

A Division of I-T-E Circuit Breaker Company

Export Division: 13 East 40th Street, New York 16, N. Y. • *In Canada:* BullDog Electric Products Co. (Canada) Ltd., 80 Clayson Road, Toronto 15, Ont.

ELECTRIC HEAT CONTRACTORS:

This is the radiant heating panel backed by the PYREX trademark



You can rely on the proven dependability of this low-temperature source panel to increase your electric home heat installations.

You can recommend and install the PYREX brand glass panel *confidently.*

It's available to you now with years of satisfactory performance behind it. Homeowners are using it in built-in systems and in portable units.

High wattage output

Because PYREX radiant panels are tempered borosilicate glass, they pack more watts per unit. One PYREX unit, for example, gives you up to 3,000 watts output in permanent installation heaters. And tempering further increases resistance to thermal shock and mechanical impacts.

With this panel, you lower the initial cost of an electrical heating system and you reduce installation costs, as well.

Full radiation

The entire back surface of the PYREX panel is coated with an electrically conductive metallic deposit. Thus, the entire panel radiates long-wave-length infrared rays.

With the PYREX panel you get lower operating costs than with other, less efficient elements. And there is no heavy starting surge.

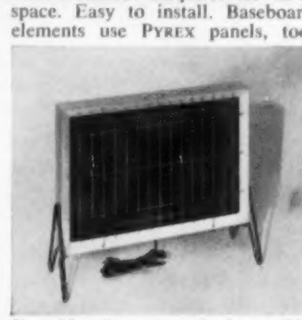
Full year warranty

Every PYREX panel is warranted by Corning Glass Works for one full year. If, during the first year of service, a panel fails due to a defect in the glass panel, Corning will replace the panel at no cost.

Send for full information

If you are in one of the growing number of areas served by utilities anxious to increase electric heating to balance their winter-summer loads, this panel can be of profitable help to you. To find out how, write, wire or phone us.

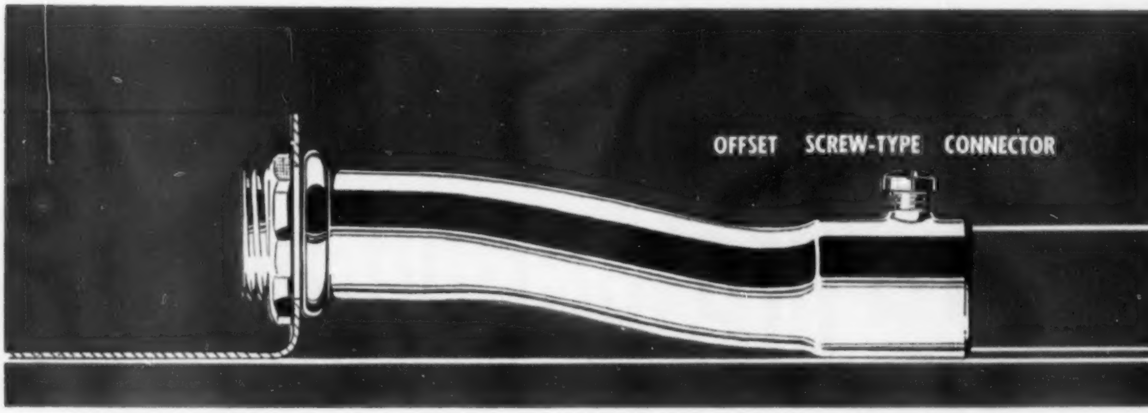
Wall-mounted. Requires no floor space. Easy to install. Baseboard elements use PYREX panels, too.



Portable. Instant, safe heat. The rugged, tempered glass withstands the jolts of frequent moving about.

CORNING GLASS WORKS, CORNING, N. Y.
40-5 CRYSTAL STREET

Corning means research in Glass



This exclusive offset connector made by

Tube-weld

presents a new concept in electric fitting design!

Bending offset connectors wastes time and money! Tube-Weld eliminates this costly, time consuming chore with this new concept in design. Developed after careful study of electrical contractor needs – this unique fitting allows fast, economical connecting and wiring. Tube-Weld's one-piece, thin wall steel tubing means increased inside diameters. Its longer length means greater bearing support and rigidity of conduit.

You can put your confidence in Tube-Weld fittings:

- in the oversized hardened steel set screws that are *staked for permanency!*
- in the uniformly flat connector shoulders that assure perfect centering in the box.
- in the rolled instead of cut threads which have 54% greater stripping strength and 66% greater snapping strength according to an independent testing laboratory report.
- in the smooth, lustrous zinc finish and carefully beveled edges–your assurance of workmanship that is unsurpassed in the electric fitting field.

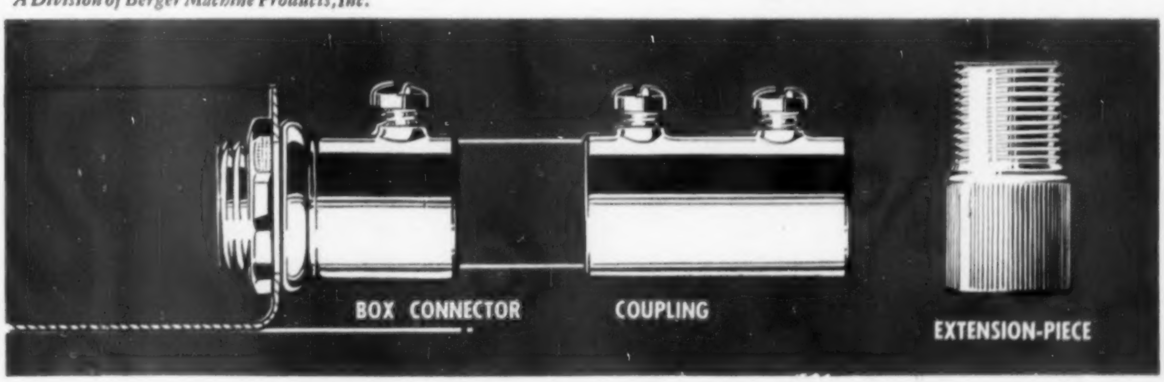
Tube-Weld fittings are available in ½", ¾" and 1" sizes. They are carefully and smartly boxed for ease in shelving and identification. For descriptive brochure and additional information, write or call: **Electric Tube Products**

74-16 Grand Ave., Maspeth (N.Y.C.) N.Y.
DEfender 5-8000

UL

CONNECT WITH ETP FOR ECONOMY

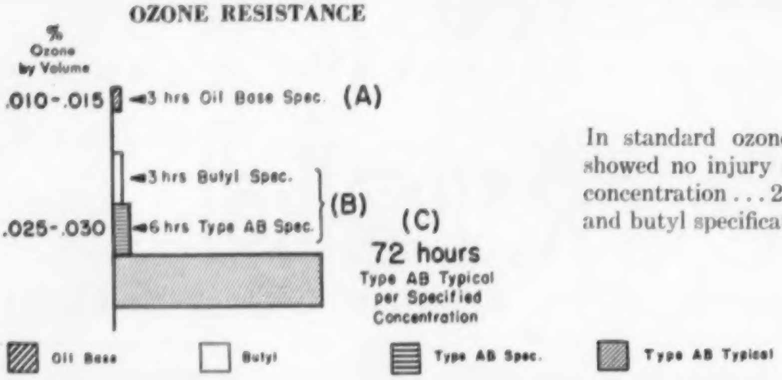
A Division of Berger Machine Products, Inc.



3 tests show butyl rubber-

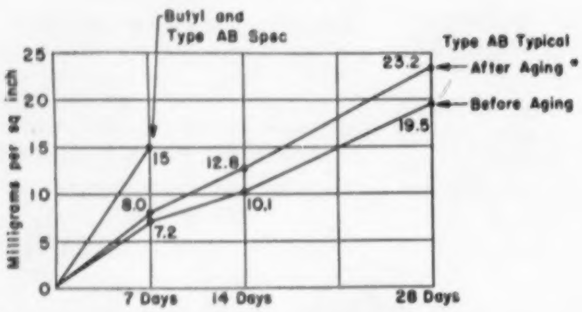
Extra protection against

OZONE RESISTANCE



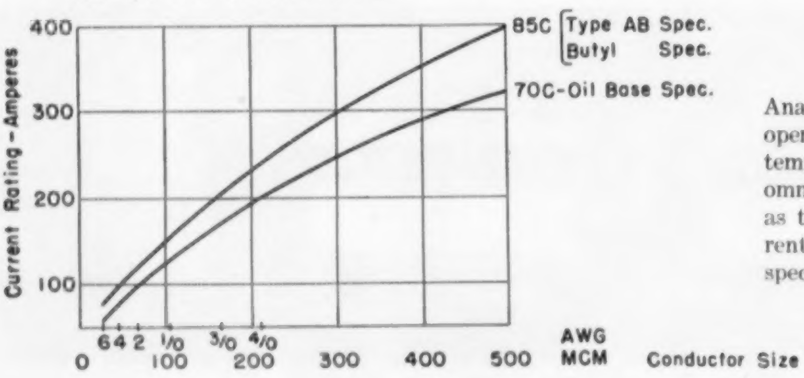
In standard ozone-chamber test, Type AB insulation showed no injury after 72 hours in 0.025-0.030% ozone concentration . . . 24 times longer than required by oil base and butyl specifications.

MOISTURE ABSORPTION



For the mechanical moisture absorption test, the industry has regarded 15 milligrams increase in weight per square inch of exposed surface, after 7 days' immersion at 70C, as a criterion for satisfactory moisture resistance. Type AB easily meets that requirement—in fact, after 28 days of immersion it is only a fraction above the 7-day requirement.

OPERATING TEMPERATURE



Anaconda recommends Type AB for operation at 85C maximum operating temperature. Industry standards recommend 70C for oil base. That means, as the graph shows, Type AB's current-carrying capacity exceeds oil base specifications by 22%.

insulated Durasheath* Cable has

ozone, heat and moisture

Anaconda exclusive Type AB butyl rubber insulation resists ozone far longer than needed to prove its high ozone resistance . . . absorbs far less moisture . . . has 22% more current-carrying capacity.

Standards are set up for your protection—but most standards state minimum requirements.

Anaconda's Type AB butyl-insulated cable performance exceeds its own specification requirements and goes far beyond industry requirements—gives you an extra margin of protection against the major enemies of long cable life.

Butyl rubber has *inherent* resistance to ozone, heat and moisture. Thus Anaconda has been able to concentrate on the development and improvement of other desirable properties.

The pay-off is in your operations—in longer cable life . . . in less maintenance . . . in lower over-all operating costs. The Man from Anaconda will be glad to give you full details about Type AB-insulated Durasheath and other Type AB-insulated high-voltage cable. Why not call him today? Or for more information, write Anaconda Wire & Cable Company, 25 Broadway, New York 4, New York.

*Reg. U. S. Pat. Off.

PIONEER IN BUTYL INSULATION **ANACONDA®**

1 win a GE all-electric kitchen

Electricians and Electrical Contractors!
It's Easy!
Nothing to Buy!
100 Second Prizes!

PICK UP FREE ENTRY BLANK AT YOUR G-E TRUMBULL DISTRIBUTOR

Complete the sentence "I like G-E Trumbull safety switches, circuit breakers and service entrance equipment because . . ." in 25 words or less. No labels to send in. Mail your entry blank to Trumbull Components Department, Section TC7, General Electric Company, Plainville, Connecticut. Contest subject to Federal, state and local regulations.

Think how happy your wife would be with this bright new G-E All-Electric Kitchen! Includes*: General Electric Washer-Dryer Combination, Disposall® Sink, Automatic Dishwasher and Built-in Range—all under one gleaming, easy-to-clean, stainless steel counter. Plus the famous new Built-in Oven and Wall Refrigerator! Without moving more than a few steps either way, your wife can do the family wash, get a whole day's dishes done, cook a big meal, and dispose of the garbage—automatically! And to top it off, you'll get the free services of a professional architect to help you plan your dazzling new G-E All-Electric Kitchen! Here's an opportunity you won't want to pass up.

2 100 Second Prizes: G-E Automatic Skillets!
Cooks everything from a simple breakfast to a complete dinner—automatically. Fries, bakes, stews, braises. Simply set temperature selector for desired heat.

ENTER TODAY!
Contest closes June 24, 1956

*Appliances shown in a complete kitchen

Progress Is Our Most Important Product

GENERAL ELECTRIC

GARCY *Speed-line*®

PATENT PENDING

LABOR SAVING

on continuous-row lighting installation

WINS CONTRACT

for Electric Service Co., Eau Claire, Wis.

1 **12:53 PM**—Everything ready to begin installation in this typical Eau Claire classroom: Hickeys, to take Garcy Adjustable Stem Hangers, have been previously attached to ceiling. Garcy Speed-line Visualier bulk-packed fixtures have not yet been removed from cartons.

2 **1:00 PM**—Wireway channels have been unpacked and laid out along sawhorses. Wireway covers have been removed and Speed-line couplings, inserted between fixtures, are being fastened in place. The four individual fixture wireways now make a rigid continuous 28-foot assembly.

CLASSROOM LIGHTING INSTALLED

5 **1:20 PM**—The first row has been leveled and lamped, and the workman is attaching the last of the separate louver shields. Meanwhile the other two workmen have been repeating the wireway assembly procedure for the second row.

6 **1:32 PM**—The second lamp row has been assembled and installed . . . just 12 minutes after completion of the first row.

Estimating that $4,482 could be saved by using the Garcy Speed-line System instead of separate external mounting channels, Electric Service Co. submitted the winning bid for relighting the Eau Claire Senior High School.

The potential savings of the Speed-line System were well known to E. F. Klingler & Associates, architects, who supervised the job of relighting and rewiring 22 standard classrooms, about 750 feet of corridor, plus storage space, toilets, etc. The architects invited all bidders to submit an alternate figure based on Speed-line savings. In their successful bid, Electric Service Co. figured that Speed-line would save more than 50% of installation labor costs. Their faith in Speed-line was amply justified . . . as indicated by the remarkable series of progress photographs pictured here.

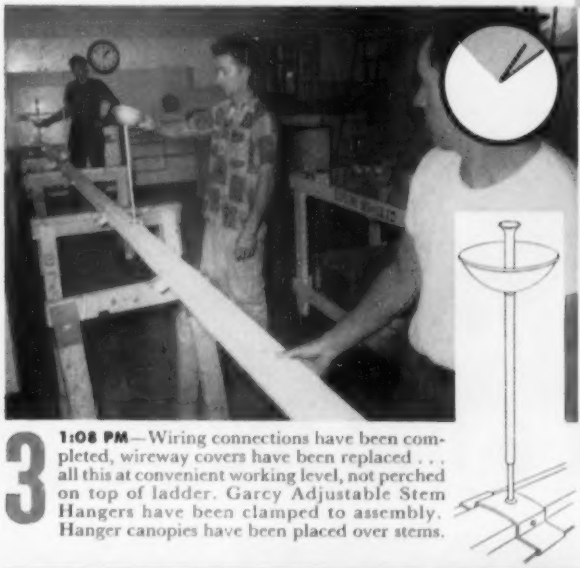
Learn how Speed-line can cut installation labor costs 50% and more on continuous-row lighting

Send today for Bulletin 551-L

GARCY

Quality by Design

GARDEN CITY PLATING & MFG. CO., 1730 N. Ashland Ave., Chicago 22, Ill.
In Canada: Garcy Co. of Canada, Ltd., 191 Niagara St., Toronto

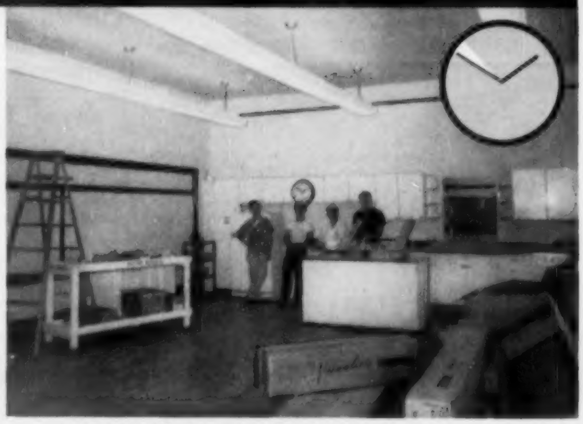


3 **1:08 PM**—Wiring connections have been completed, wireway covers have been replaced . . . all this at convenient working level, not perched on top of ladder. Garcy Adjustable Stem Hangers have been clamped to assembly. Hanger canopies have been placed over stems.

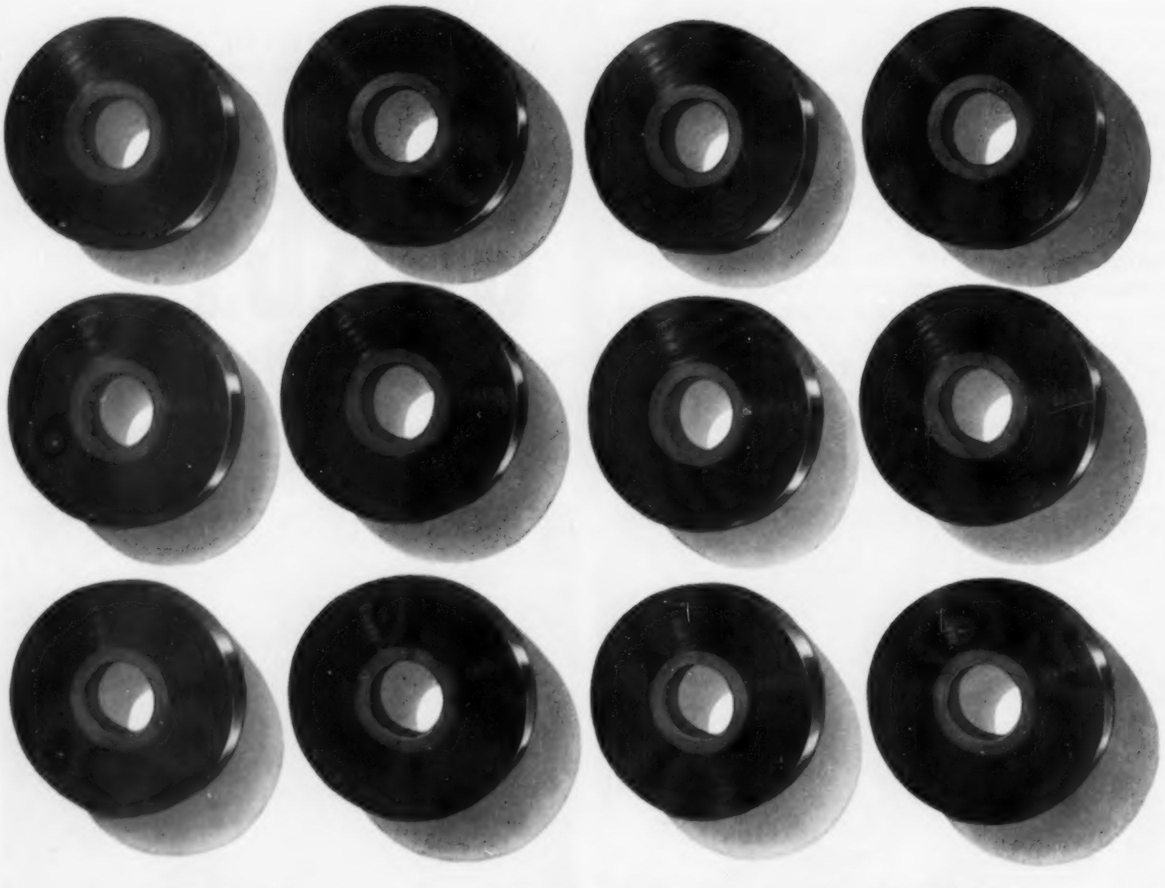
4 **1:09 PM**—In one minute's time the rigid 28-foot assembly has been carried up the ladders, and stem hangers hooked into ceiling hickeys. No lock nuts, no washers are needed.

BY 3 MEN IN LESS THAN 1 HOUR

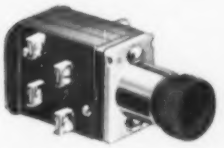
7 **1:43 PM**—Wireway for the third and last row is carried to the ceiling.



8 **1:51 PM**—All three rows installed, lamped and lighted. Elapsed time, 58 minutes. Saving in labor costs permits budget-wise use of Garcy Visualier, finest in school and office lighting.



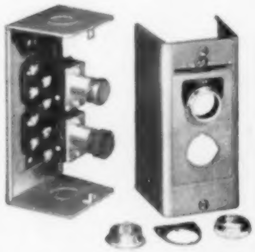
ALLEN-BRADLEY
HEAVY DUTY PUSH BUTTONS



Bulletin 800 heavy duty STOP button ready to mount in enclosure. (See below)

These new Bulletin 800 heavy duty push buttons are the modernized version of that old reliable line of A-B heavy duty stations. Advantages—until now restricted to the oiltight stations for machine tool use—have been built into these new heavy duty stations—and you'll like the result.

For instance, each button or pilot light is a self-contained unit which can be mounted singly or in groups—vertically or horizontally—in a variety of standard Allen-Bradley enclosures, with the name plate reading in the right direction. Double break, silver alloy contacts used throughout. Send for Bulletin 800.



A small stock of standard components lets you assemble any special heavy duty station. There is no waiting for special push button stations.

Allen-Bradley Co., 1316 S. Second St.
Milwaukee 4, Wisconsin

A-B Quality

In Canada
Allen-Bradley Canada Ltd., Galt, Ont.

ALLEN-BRADLEY
QUALITY
BULLETIN 800 PUSH BUTTONS

5-56-MR

More scope for selection

IN THE FULL LINE
OF GENERAL ELECTRIC CABLES

For more versatile, effective lighting

amplex
Swivelite

Accent Lighting Fixtures . . . Specified by Experts

Amplex Swivelite C12SH "Adapt-A-Unit" construction permits complete interchangeability for all parts for constantly new lighting setups.

Amplex Focalite Won't tip over—easy to focus—most adaptable fixture for lighting displays.

Colorbeam Reflector Lamp Amplex Colorbeams come in 14 striking colors, rated life of 2,000 hours.

Yes, the "Adapt-A-Unit" construction of Amplex Swivelite fixtures permits endless variety in achieving beauty and concentrated light for attention-getting effects . . . with a minimum number of basic units. These are without question the finest, most adaptable "working tools" for achieving up-to-date lighting with real *selling power*. And for more striking and colorful light, specify Amplex Spots, Floods and Colorbeam Reflector Lamps, designed especially for Amplex Swivelite fixtures. Write for new catalog describing the Swivelite *big four* exclusive features that produce effect, efficiency, economy.

amplex
CORPORATION
Dept. ECM-556, 111 Water St., Brooklyn, N. Y.

Why the new Blackhawk *Featherweight*

REVOLUTIONIZES BENDING

90° bends in 1 setup send bending costs tumbling! Blackhawk's new S-130 bends pipe so fast, so perfectly, at such low cost that practically all need for factory-formed ells is eliminated. It makes possible infinite combinations of bends *right on the job.*

"Featherweight" portability

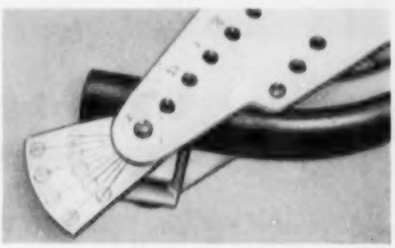
Aluminum alloy frame and shoes are rigid and strong — yet surprisingly lightweight for greater portability, easier assembly and maneuverability overhead, on bench or floor. Keeps crews happier and more productive!

"Featherweight" S-130 bender obsoletes all other equipment for bending ½ thru 2-inch rigid conduit and pipe

It's as modern as the jobs electricians work on today — with all the astounding speed, ease, light weight and precision in bending that electricians themselves asked for. Check these important features, and you'll see why it's good business to put the new "Featherweight" S-130 on your jobs — why it starts paying for itself *immediately* through dramatic savings in both labor and material costs.

Kit includes "Porto-Power" hydraulic 10-ton unit plus bending equipment for six sizes of pipe and conduit, ½ thru 2 inches.

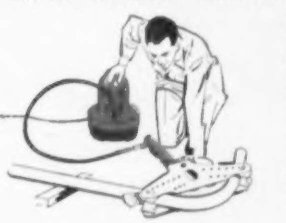
S-130 Kit — $189.00



"Optik-Angle" gauge

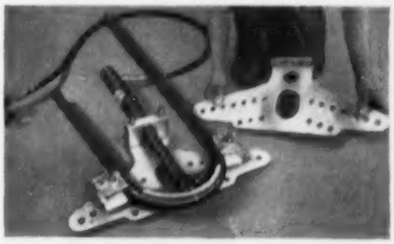
Eliminates guesswork and time-wasting measuring in controlling degree of bend. Degree is constantly shown by above simple gauge, which is mounted right on bender.

. . . and you can make a 90° bend in 2" pipe in less than 60 seconds with electric-power pipe bending!



Blackhawk's P-182 electrically-driven hydraulic pump brings remarkably economical, speedy operation to pipe bending. By eliminating hand pumping, the P-182 ends manual effort . . . you can turn out "production" bends three to six times faster! Can pay for itself on the first job.

S-132 Pipe Bender Kit same as S-130 but with P-182 pump in place of hand-operated pump.......... **$485**



New longer-stroke ram

Extends full 10 inches. Makes 90° bends in one stroke with only one setting of pipe in shoes. Forms up to 180° bends faster than ever, too! Removable top plate and "Lock-On" shoes for quick positioning of pipe.

Order Blackhawk Electrician's Hydraulic Tools from your electrical wholesaler or industrial distributor today. Write for free literature direct to Blackhawk Mfg. Co., Dept. P-2056, Milwaukee 46, Wis.

Prices subject to change without notice

BLACKHAWK®

world's largest manufacturer of HYDRAULIC TOOLS

IF YOU THINK **DUCKS** ARE MOISTURE-RESISTANT,

GET ACQUAINTED WITH THIS NEW

ROEBLING ALL-RUBBER CONTROL CABLE

HERE'S A NEW CONTROL CABLE entirely built of non-hygroscopic materials. Conductors are covered with a special low capacitance moisture and heat-resistant insulation. In addition the insulation on each conductor is protected by a neoprene jacket. Rubber fillers are vulcanized and completely fill all interstices. Asbestos-neoprene tape binds cable core during processing and becomes an integral part of the tough, overall, Roeprene sheath Wicking, or migration of moisture, longitudinally, is avoided.

In this new Roebling All-Rubber Control Cable there is no deformation of conductor insulation or sheath. The completely filled core prevents sheath damage and moisture absorption. Conductors strip free and clean for easy splicing and terminating. Each conductor is identified by clear, indelible printing.

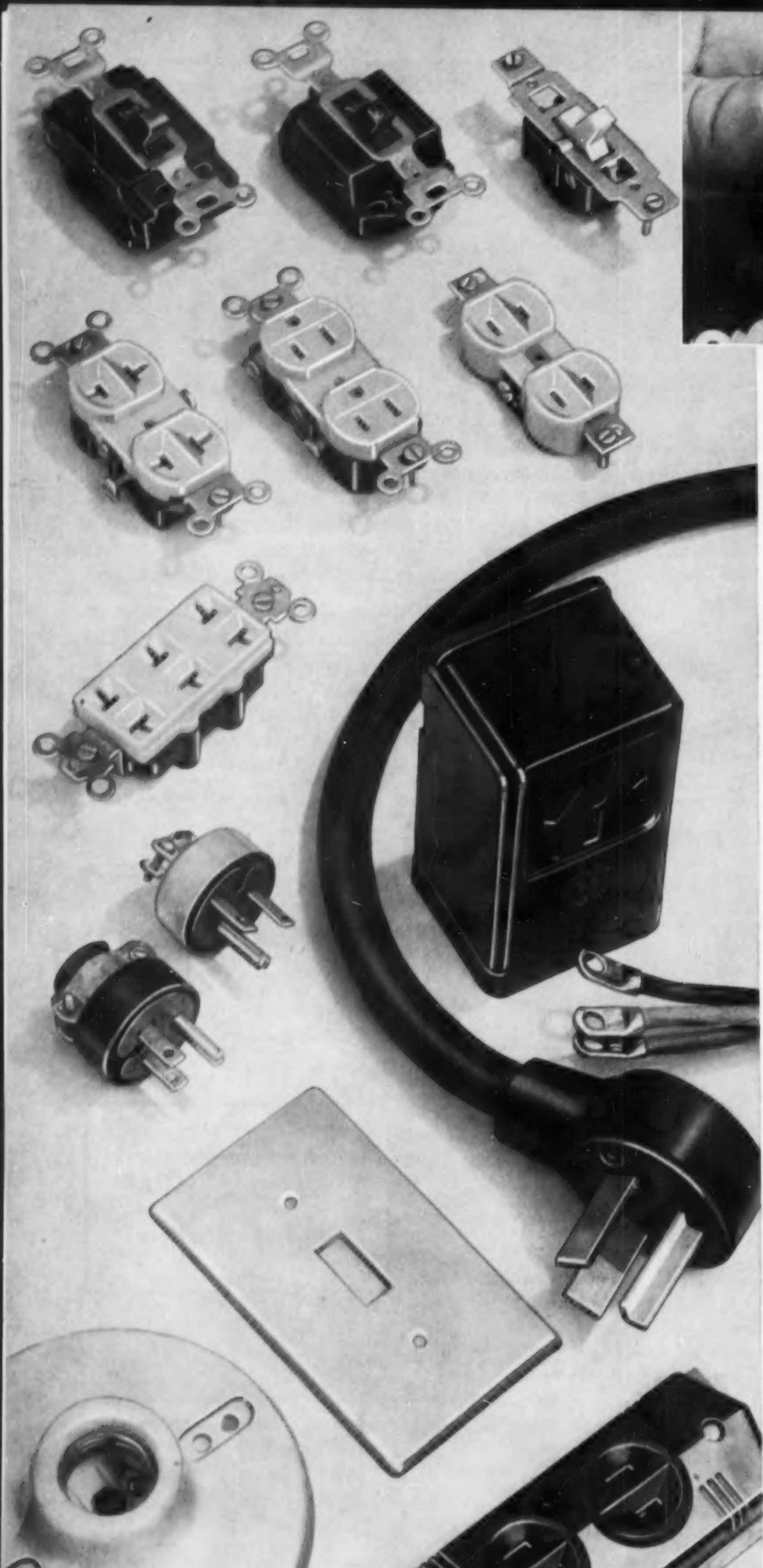
Write for full information.

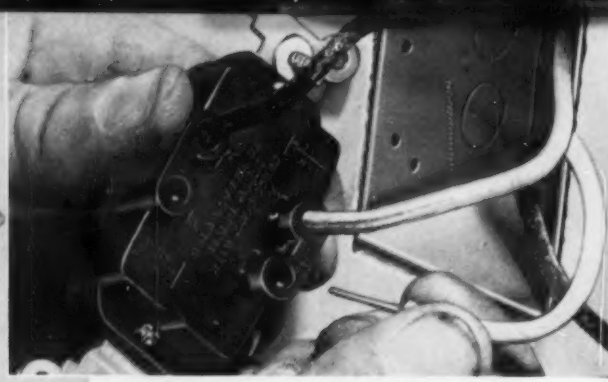
ROEBLING ELECTRICAL WIRES AND CABLES ARE AVAILABLE WITH EITHER COPPER OR ALUMINUM CONDUCTORS

ROEBLING

Subsidiary of The Colorado Fuel and Iron Corporation

JOHN A. ROEBLING'S SONS CORPORATION, TRENTON 2, N. J. BRANCHES: ATLANTA, 934 AVON AVE. • BOSTON, 11-15 STILLINGS ST. • CHICAGO, 5525 W. ROOSEVELT RD. • CINCINNATI, 3253 FREDONIA AVE. • CLEVELAND, 13225 LAKEWOOD HEIGHTS BLVD. • DENVER, 4801 JACKSON ST. • DETROIT, 915 FISHER BLDG. • HOUSTON, 6216 NAVIGATION BLVD. • LOS ANGELES, 5340 E. HARBOR ST. • NEW YORK, 19 RECTOR ST. • ODESSA, TEXAS, 1920 E. 2ND ST. • PHILADELPHIA, 230 VINE ST. • PITTSBURGH, 1723 HENRY W. OLIVER BLDG. • SAN FRANCISCO, 1740 17TH ST. • SEATTLE, 900 1ST AVE. S. • TULSA, 321 N. CHEYENNE ST. • EXPORT SALES OFFICE, 19 RECTOR ST., NEW YORK 6, N. Y.





G-E PRESSURE-LOCK TERMINALS make wiring easy, eliminate binding screws. Wire is merely stripped and pushed into terminal for firm, dependable pressure connection. Available in a complete line of outlets, switches, and lampholders.

233 new or added to the

With the newly expanded General Electric line of wiring devices you can handle any wiring job. Look over your distributor's display of this line of switches, outlets, lampholders, plates, and special purpose devices. You'll find a wide assortment in a broad range of grades, from the finest specification and heavy duty grades to the low cost competitive grades. Here's everything needed for commercial and industrial jobs; for residential and rural jobs.

During the last two years alone the G-E line grew by the development and introduction of 233 new or completely redesigned wiring devices. For faster, easier wiring, G-E pressure-lock terminals are now featured in a complete line of outlets, switches, and lampholders, including surface devices. Other developments include stronger, more rigid mounting straps for outlets and switches; new and improved remote control components; nylon-jacketed heating wire for radiant heating systems, new lighted handle for silent mercury switches; and many other entirely new features that help you meet your growing wiring requirements.

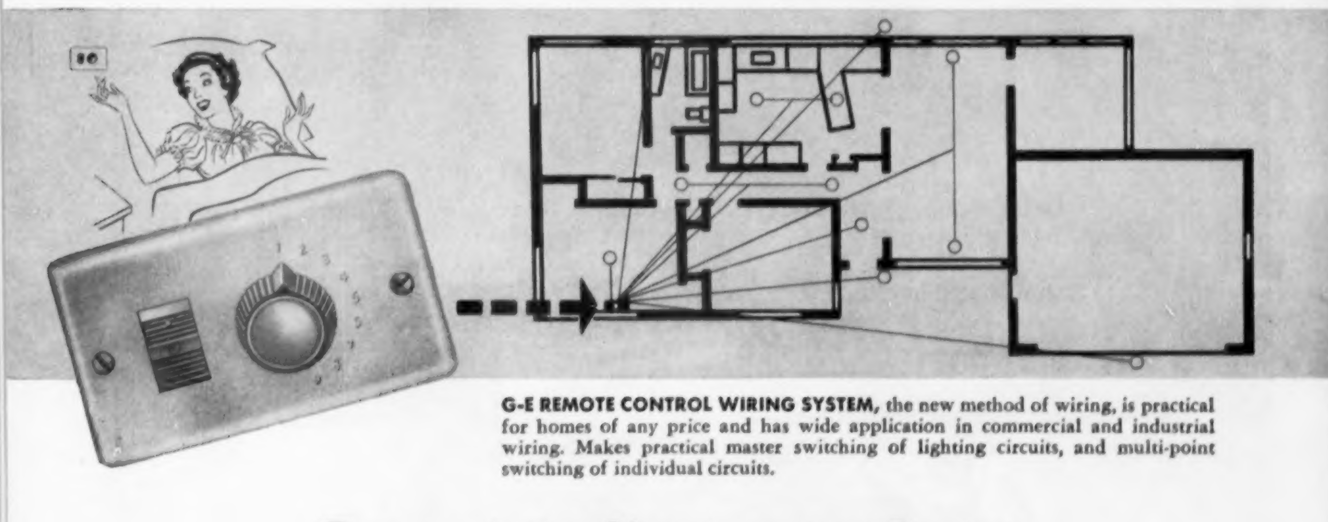
Yes, you can look to General Electric for the newest developments continually . . . wiring devices that not only answer the electrical contractor's needs but also can be depended on for extra service and long life.

NEW G-E MERCURY SWITCH has a handle lighted by a tiny neon lamp. Handle lights when switch is in OFF position. Will give years of service. Locates switch in dark and serves as a pilot light.

G-E WATCH DOG STARTERS provide automatic lockout of failing lamps, protect ballast and fixture wiring, and eliminate blinking — outlasts ordinary starters up to ten to one. In addition, the FS-400 prevents premature burn-outs of lead lamps.

redesigned Wiring Devices have been G-E line during the last two years alone!

Extensive as the G-E wiring device line is, General Electric is constantly developing new products and new ideas. Some improvements are designed to save installation time and make wiring easy: like self-tapping, plaster-cleaning screws (now standard on all switches and outlets) held in position for quick mounting by fiber washers. Some G-E developments improve the wiring system: with remote control, the convenience of multi-point and master switching is offered along with the safety of low voltage. Always, General Electric developments serve the contractor and his customers dependably and at low cost. Wiring Device Department, General Electric Company, Providence 7, Rhode Island.



G-E REMOTE CONTROL WIRING SYSTEM, the new method of wiring, is practical for homes of any price and has wide application in commercial and industrial wiring. Makes practical master switching of lighting circuits, and multi-point switching of individual circuits.

Progress Is Our Most Important Product

GENERAL ELECTRIC


O.Z. pull boxes
SAVE TIME!
SAVE SPACE!
SAVE MONEY!
HEAD "B"
ASSEMBLED PULL BOX
The easiest, most economical way to speed installation of conduit—of any size from ½" to 6"—is to use O. Z. Pull Boxes. Two hot dip galvanized malleable iron units fitted to an oversize length of pipe replace the conventional, bulky and costly pull box . . . cuts labor time in half!
O. Z. Pull Boxes are available in four designs: standard (Type "PB"); weather-tight (Type "PBW"); explosion proof and thin wall conduit. The oversize sleeve can be cut to required length "on the job" from standard conduit, or furnished to your specifications by O. Z.
TYPE "B" INSULATED BUSHING
JUST TWO SIMPLE ASSEMBLY STEPS
Call your local O. Z. distributor, or write direct to the company for complete information.
1. Slide head "A" with sleeve over the conduit end. Attach head "B" on opposite conduit.
TYPE "PBW"
OVERSIZE SLEEVE
SLIDING HEAD "A"
SET SCREWS
CONDUIT
2. Simply pull cables, loop and feed back into oversize sleeve. Slide head "A" with sleeve into position and screw sleeve into head "B". Tighten set screws to lock "A" in position.
O.Z. ELECTRICAL MANUFACTURING CO., INC.
262 BOND STREET · BROOKLYN 17, N. Y.
San Francisco Plant: 749 Bryant Street, Garfield 1-7846
CAST IRON BOXES
CABLE TERMINATORS
POWER CONNECTORS
SOLDERLESS CONNECTORS
GROUNDING DEVICES
CONDUIT FITTINGS

...*if I were you*
I'd use CLIFTON conduit

CLIFTON Rigid and EMT Conduit have made a lot of friends for me and my wholesale firm over the years. My customers have learned to trust CLIFTON and with good reason.

CLIFTON Rigid and EMT Conduit are made by CLIFTON'S special hot-dip method which bonds a uniform protective zinc coating to both inside and outside of the tubing. No other method has been found to be more satisfactory or to give us much protection as CLIFTON'S. Take it from me, CLIFTON means top quality on-the-job protection.

Clifton Rigid Conduit

Clifton EMT Conduit

Wherever used in every type of construction, CLIFTON has proven itself easier to install, and thoroughly dependable. A CLIFTON Raceway installation permits easy rewiring to accommodate the ever-increasing demands of electrical loads, as emphasized by the national adequate wiring program. I suggest to all my customers that they stop switching and standardize on CLIFTON Rigid and EMT. I think it's good business both for them and me.

CLIFTON Rigid and EMT Conduit are approved by Underwriters' Laboratories, Inc., conforms with Federal Specifications WW-C-581C, WW-T-806B, and ASA Specifications C-80.1—1953, C-80.3—1953.

Your Best 2 Word Specification

CLIFTON CONDUIT

Other* CLIFTON *Quality Products:

CLIFTON Flexible Steel Conduit · CLIFTON Armored Cable · CLIFTON Plastic Covered Steel Conduit
CLIFTON Unarmored Service Entrance Cable
CLIFTON (Cliftx) Non-Metallic Sheathed Cable
CLIFTON Building Wire TW-R-RHRW-RR-S-SJ
CLIFTON Elbows and Couplings · CLIFTALL UF

WRITE TODAY
For Full Information

Warehouses Throughout the Country.

Representatives in Principal Cities

Clifton CONDUIT CORPORATION

MAIN OFFICE
75 Montgomery St.
Jersey City 2, N. J.

FACTORIES
BALTIMORE, Maryland
MEMPHIS, Tennessee

WIRE · CABLE · RIGID CONDUIT · ELECTRIC METALLIC TUBING · CLIFTALL UF

"The LIVE BETTER . . . Electrically campaign offers exceptional opportunity for the electrical contractor, both in a business sense and in the contribution it can help him make toward the building of a better America.

"...six and a quarter billion dollars' worth of work..."

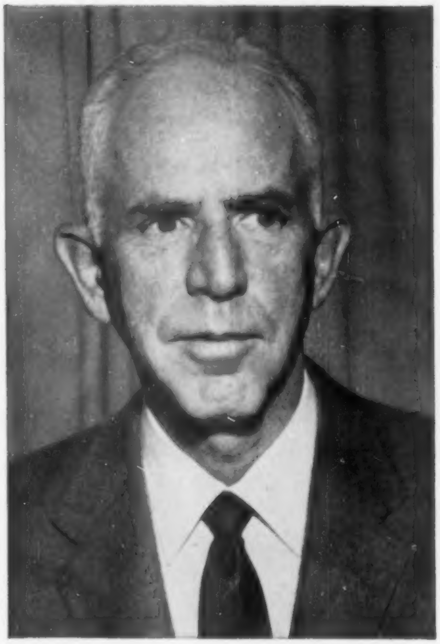
"One of the conservative estimates is that twenty-five million homes now are at such a low level of electrical efficiency that modernization is urgently necessary for the minimum level of safety and economical operation.

"Home electrical modernization alone is an estimated six and a quarter billion dollars' worth of work. I have not the slightest doubt that the LIVE BETTER . . . Electrically campaign will stimulate a most pressing demand for expanded electrical systems in the home."

How you can make the most of LIVE BETTER...

Nationally, and locally, the LIVE BETTER . . . Electrically campaign will make the American public more conscious of the benefits of electricity *in the home*. More than half of all homes in this country today were built prior to 1925. These homes were wired for lights and the few (less than twenty) electrical appliances then available. Today there are over fifty products and appliances the home owner plans to buy. Residential lighting, as we know it today, was never dreamed of twenty or thirty years ago.

The LIVE BETTER . . . Electrically program will build a demand for modern home wiring and the electrical prod-



Oliver F. Burnett,
President, National Electrical Contractors Association

Electrically

ucts that make a home more valuable, more comfortable . . . housework easier and less time-consuming. This demand will bring with it an even greater demand for proper wiring, both in older homes and new ones being built.

A new 64-page book has been produced to help you help your clients live better electrically. In digest size, this book contains complete plans for "load-matched" residential wiring systems . . . a new and realistic approach to a steadily growing problem. For your copy, call or write your local electric utility company, or mail coupon at right with 10¢ to cover cost of handling.

LIVE BETTER . . . *Electrically*
P.O. Box 505
Great Neck, New York

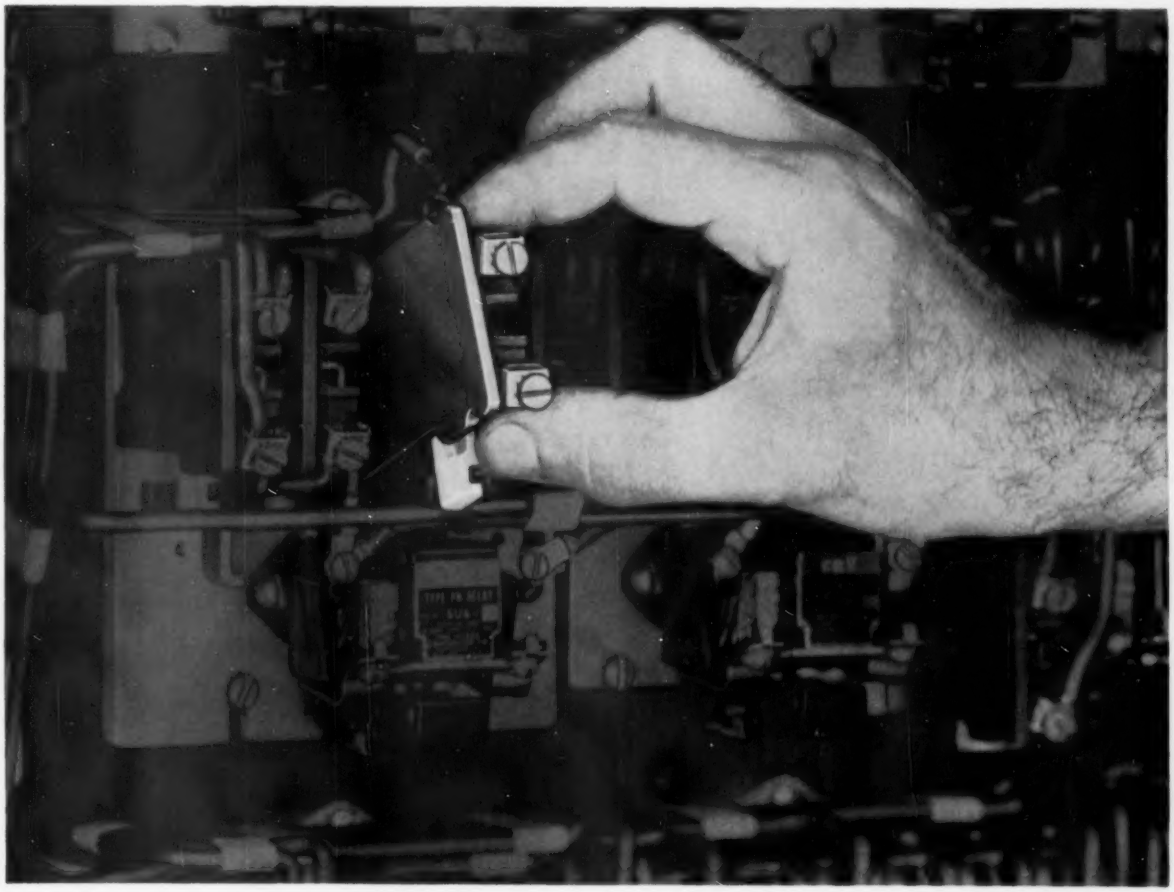
Please send me a copy of book entitled "How to help home owners LIVE BETTER . . . *Electrically.*" I enclose 10 cents to cover cost of handling.

*Name*____________________

*Street Address*____________________

*City*__________ *Zone*____ *State*________

11-902-6



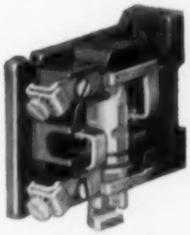
You can easily remove a single pole from any CLARK Type "PM" Relay

Each pole in the new CLARK heavy-duty relays is an integral unit that can be quickly removed or replaced *from the front* without disturbing other poles. You need disconnect only two wires and loosen one mounting screw—regardless of the number of poles in the relay. Compare this with other types of relays where the whole device must be removed to accomplish the same thing. For example, with a conventional 6 pole relay, 14 wires and 3 mounting screws must be removed.

All terminals are located on the front. They are "pressure" type, eliminating need for looping wire. Coil-changing and magnet replacement can also be done quickly from the front without removing relay from panel.

Write for Bulletin PL-7305

Each pole is contained in its own melamine housing.



A short circuit through one set of contacts is confined to a single pole and will not destroy the whole relay. Enclosed top protects from dust and dirt, and serves as wiring shelf.

The **CLARK CONTROLLER** *Company*

Engineered Electrical Control **1146 East 152nd Street • • Cleveland 10, Ohio**

IN CANADA: CANADIAN CONTROLLERS, LIMITED • MAIN OFFICES AND PLANT, TORONTO

ADV.

Introducing "Skimpy Wiring" to your homeowner customers!

More than 15,793,000 readers of the Saturday Evening Post and This Week national magazines will see this dramatic Kennecott ad featuring "Skimpy Wiring"—Dead End Kid of the electrical business!

It's another nation-wide advertisement in the Kennecott campaign for better home wiring with copper—a drive that *helps you get more re-wiring jobs!*

Let Kennecott help you with your own local better wiring campaign, too!

SEND FOR FREE PROMOTION MATERIAL

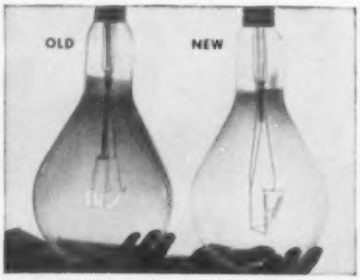
Send today for free reprints and poster-sized blow-ups of *Kennecott's* full-page national advertisements. Get free copies of the educational booklet, "The ABC of Home Wiring." Ask for complimentary home wiring Wall Chart, mat service folder and list of *at-cost* prices for large-quantity orders of all material available. No cost, no obligation! Just write: Kennecott Copper Corp., Dept. EC 56, 161 East 42nd St., New York 17, N. Y.

Advertisement

G-E LAMPS GIVE YOUR CUSTOMERS MORE FOR ALL THEIR LIGHTING DOLLARS

Help Your Customers Cut Their Lighting Costs

...and build sales and good-will at the same time. These new and improved G-E lamps can do many jobs better for your customers — save them money, increase your profits.

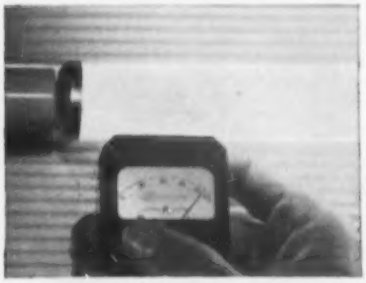


Using the "stand-up" filament to increase light output by as much as 15%, the Bonus Line lamp is now available in 500, 750, and 1000-watt sizes. Note reduction in bulb blackening after same hours of use.

☑ **NEW G-E LAMPS**—Each year, General Electric introduces many new lamps that can cut operating costs. One, the G-E Quartz Infrared, introduced in 1955, is already playing a vital role in many industrial and research applications. Hot enough to melt aluminum, they are used to simulate the heat produced by supersonic flight on aircraft parts.

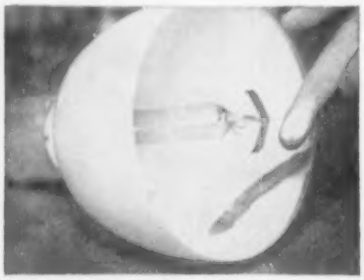
Another cost-cutting lamp recently announced by General Electric is the High Output fluorescent—today's most powerful fluorescent lighting tool. For top color rendition, suggest the DeLuxe Cool or Warm White High Output which give as much light as other fluorescent types in standard "Whites".

The smallest and hottest electrical heat source available (shown here melting aluminum) the G-E Quartz Infrared permits reduced size in many applications because of the concentrated heat it produces.



The G-E High Output fluorescent lamp gives 40% more light than other fluorescent lamp types. It gives the most light per fixture—costs least to maintain.

☑ **IMPROVED G-E LAMPS**—The 400-watt RC-1 mercury lamp became the best bargain for most indoor mercury lighting when G.E. increased its total light output 15% in 1955. This lamp uses a phosphor lining in a dual role—to reflect light *and* to improve color. It is interchangeable in most 400-watt fixtures.



Double-duty phosphor lining improves color *and* directs the light—gives more light with color *improvement*—at less cost.

The most significant development in lamp filaments since 1913 was announced by General Electric in late 1955—The Bonus Line. The new lamps give up to 15% more light for the same wattage and are less subject to bulb blackening. The value gained by this increased output can equal the purchase price of the lamp.

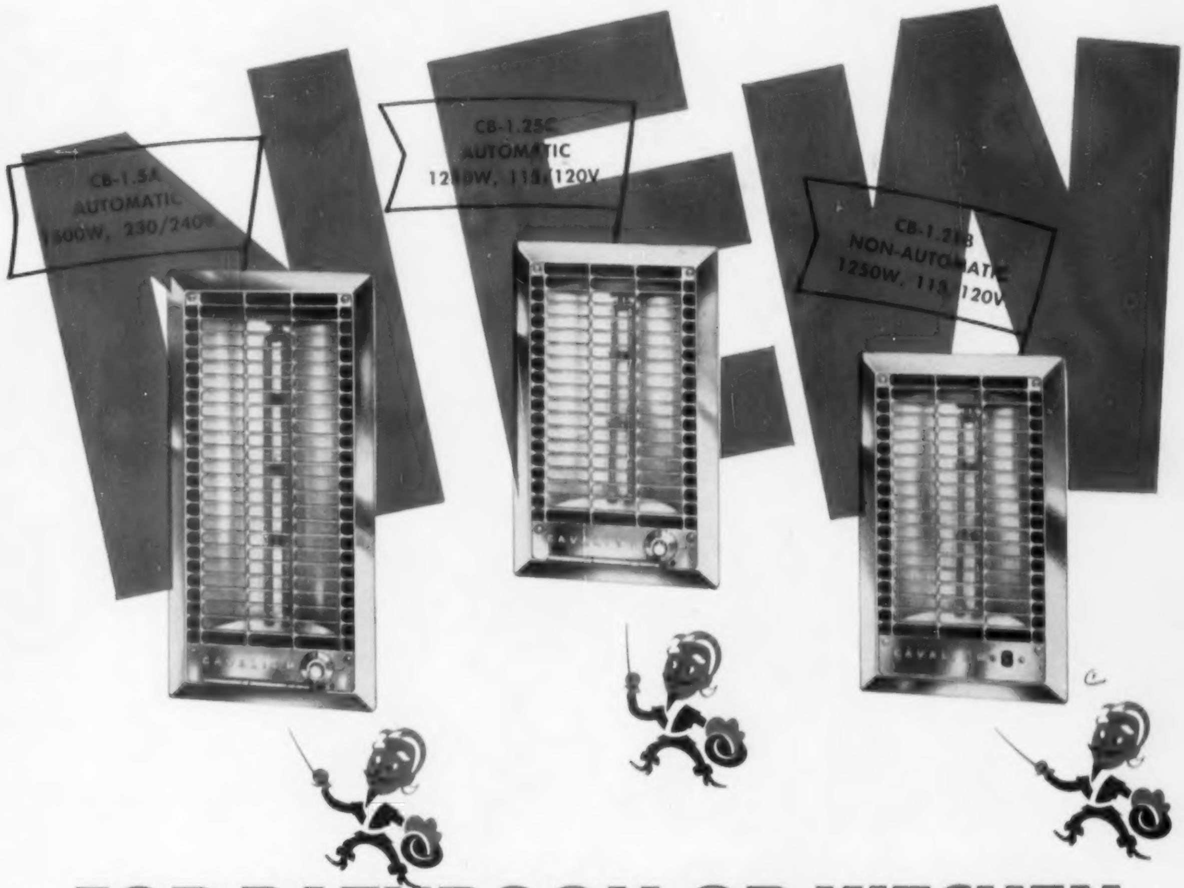
☑ **GENERAL ELECTRIC TECHNICAL HELP**—G.E. also helps users get the most from their lighting installation—more for their lighting dollar. One of our field engineers recently helped a large manufacturer cut lighting costs by over $350,000 annually, with a moderate expenditure for a new type of lamp! And he increased his light level 50% at the same time.

It is not unusual to find installations operating at less than 50% efficiency. General Electric engineering "know-how" is ready to help your customers realize the economies that come from the full exploitation of existing lighting systems. For example, we publish hundreds of bulletins each year to aid operators in dozens of commercial and industrial light fields to improve the efficiency of their lighting and decrease their costs.

☑ **FOR MORE INFORMATION** on how *you* can use new General Electric lamps, improved lamps, and General Electric technical help to cut *your* customers' costs, write, Large Lamp Dept., General Electric Co., Dept. EC-5, Nela Park, Cleveland 12, O.

Progress Is Our Most Important Product

GENERAL ELECTRIC



FOR BATHROOM OR KITCHEN

Cavalier® *LOW priced AUTOMATIC* ELECTRIC HEATERS

Absolutely NEW! Most ADVANCED! STAINLESS STEEL and ALUMINUM!

Sell constant warmth at budget price! Cavalier's new automatic bathroom heater never lets the room get cold—never wastes current in overheating. Accurate thermostat insures constant comfort. And Cavalier bathroom heaters are priced low. Your customers will be surprised that automatic bathroom heat costs so little—gives so much extra convenience.

BUILT TO STAND THE HEAT AND HUMIDITY OF BATHROOM USE. Stainless steel exteriors and solid aluminum reflectors of Cavalier bathroom heaters will literally last a lifetime. Rugged construction for lifetime usage—a feature your customers can see for themselves.

AUTOMATIC THERMOSTAT CONTROL. No more waiting for room to warm up. Cavalier automatic bathroom heaters give constant comfort. Superior quality, liquid-filled thermostat gives quick, positive response to slight temperature change. Designed for four times as much load as it actually carries. Sensitive and accurate control means comfort without waste—a plus value your customers can't overlook.

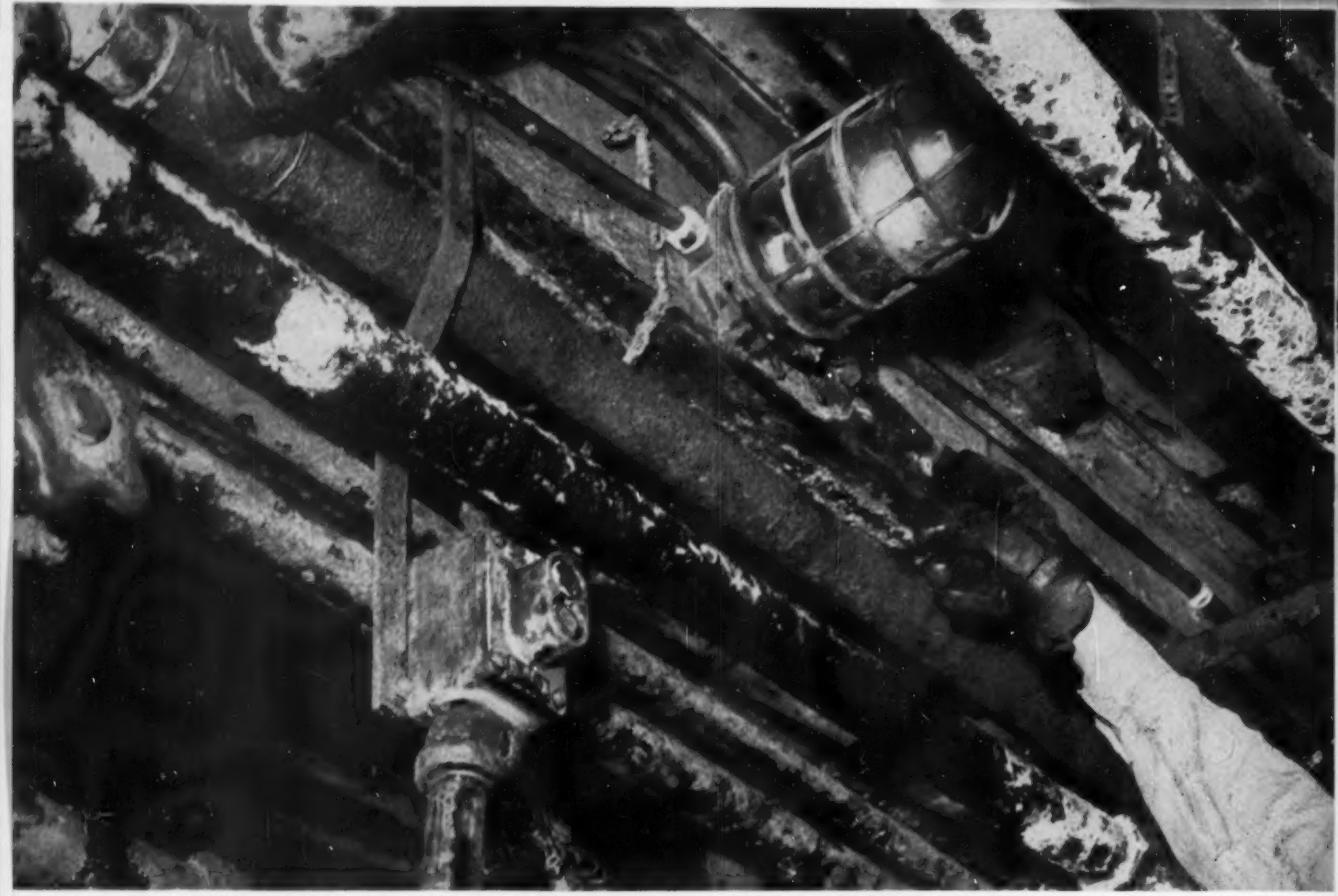
FLUSH WITH WALL. Space-saving wall insert design that makes a completely flush installation. Trim and smart looking, with lasting beauty of stainless steel and aluminum! Cool-edge exterior grille permits use with plastic tiles as readily as with ceramic tile. Grille is easily removed for cleaning. Cavalier offers more good reasons why your customers will be completely satisfied for years to come.

BRIGHT, SOLID ALUMINUM REFLECTORS for a maximum of sunny, radiant warmth. Aluminum reflectors are not heat absorbent—they project all the heat into the room. Your customers get all the heat they buy.

SELL WITH CONFIDENCE THAT YOU OFFER THE FINEST. All the genuine Cavalier quality . . . Cavalier design . . . Cavalier manufacture . . . at budget price! Show and sell the newest and hottest. It's Cavalier . . . a respected name since 1865.

1 . . . 2 . . . 3 . . . you'll agree! *These heaters will be among your most called-for items!*

See your distributor or write Electric Heating Division, Cavalier Corporation, Chattanooga 2, Tennessee.



Five-year-old installation of Sealtite is as good as the day it was installed—despite constant bath in sulphuric acid fumes, oil, steam and salt-water spray. Note, in contrast, what fumes are doing to crossbeams and metal pipes.

Nopco Chemical Co. tells how Sealtite flexible, liquid-tight metal pipe . . . costs

Flexible Sealtite is installed from motor into building so that elevator can be pulled away from building, close to delivery truck, when drums are loaded.

"Sealtite pays for itself twice over," reports H. B. Colman, Plant Engineer, Nopco Chemical Company, Harrison, New Jersey.

"In some of our departments, fumes are so corrosive they eat through wood and metal. Originally, rigid conduit was used. But in three years it was so corroded it had to be replaced. Five years ago we installed Sealtite. It still looks like new . . . and we expect it to last indefinitely!

"Second, Sealtite saves time and money because it eliminates pipe bending. And no painting or maintenance is needed. We're replacing almost all of our rigid conduit with Sealtite—both inside and outside the plant."

WHERE TO GET SEALTITE

Electrical Wholesalers stock Types U.A. and E.F. Sealtite* flexible, liquid-tight conduit in easy-to-handle coils. Be certain you ask

Why a million Amprobes save hours on the job!

The Amprobe snap-around volt-ammeter (circled above) measures voltage and current instantly, accurately, safely. This pocket-size tool saves *your* valuable time on the job while ...production equipment keeps right on rolling. You get to the heart of the problem—eliminate guesswork—save production employees valuable time on *their* jobs.

One million Amprobes in use today make Amprobe the standard snap-around tester of the industry. There's an Amprobe for every job, every budget: from 10 amp and 250 volts to 1200 amp and 600 volts AC; from $19.85 to $67.50.

AMPROBE a division of Pyramid Instrument Corp., Lynbrook, N. Y.
world's most popular snap-around volt-ammeter

MAIL FOR FREE SERVICE BOOKLETS

Pyramid Instrument Corp., Dept. M-56, Lynbrook, N. Y.

Please send me the Amprobe service bulletins checked below.

- ☐ How to cut costs and land more jobs
- ☐ How to boost your service profits
- ☐ Trouble-shooting electric motors
- ☐ Electrical serving of hermetic units

NAME____________________

COMPANY____________________

ADDRESS____________________

CITY__________ ZONE____ STATE________

Second, conduit must provide complete safety. Youngstown Buckeye is a full weight standard threaded rigid steel conduit—the type of wiring system approved by the National Electrical Code—as moisture - , vapor - , dust - , and explosion-proof for use in hazardous locations and occupancies.

Third, a wiring system must be permanently dependable. Youngstown Buckeye Conduit has proved its dependability in thousands of installations, large and small, for nearly half a century. Many thousands of miles of this product are in service today.

Specify and use Youngstown Buckeye Conduit whenever you design a modern electrical system.

BLACK ENAMELED

A protection, black enamel coating is applied inside and out by dipping. When a uniform thickness of this coating has been achieved, it is then baked to form a tight, elastic, high lustre finish—guarding against cracking in bending or forming operations during installation.

ELECTRICAL METALLIC TUBING

Absolute uniformity of weight, wall thickness and concentricity, plus protective outside coating of pure zinc and baked-on elastic enamel interior, forms this modern mirror-smooth raceway. Lightweight, easy to handle, no threads to cut, bends readily and assures safe, economical, life-time electrical installations.

ELBOWS

Size	Radius (Inches)	Offset (Inches)	Pieces Per Carton
½	4.000	6.500	50
¾	4.500	7.250	50
1	5.750	8.750	25
1¼	7.250	10.500	20
1½	8.250	11.750	15
2	9.500	13.500	10
2½	10.500	15.000	
3	13.000	18.000	
3½	15.000	20.500	
4	16.000	22.000	
5	24.000	31.000	
6	30.000	37.500	

ELECTRICAL METALLIC TUBING

Size	Nominal Diameter (Inches) Internal	External	Nominal Wall Thickness (Inches)	Feet Per Bundle
½	.622	.706	.042	100
¾	.824	.922	.049	100
1	1.049	1.163	.057	100
1¼	1.380	1.510	.065	50
1½	1.610	1.740	.065	50
2	2.067	2.197	.065	30

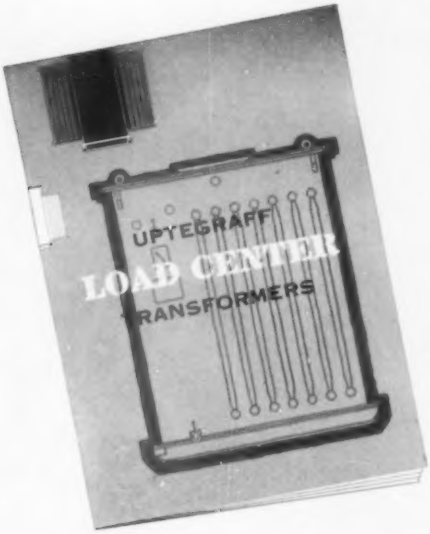
EMT furnished in 10-foot lengths, without couplings.

THE YOUNGSTOWN SHEET AND TUBE COMPANY

Manufacturers of Carbon, Alloy and Yoloy Steel

General Offices - - Youngstown 1, Ohio — District Sales Offices in Principal Cities

Ask your distributor for Youngstown Buckeye Full Weight Rigid Steel Conduit and Youngstown Electrical Metallic Tubing

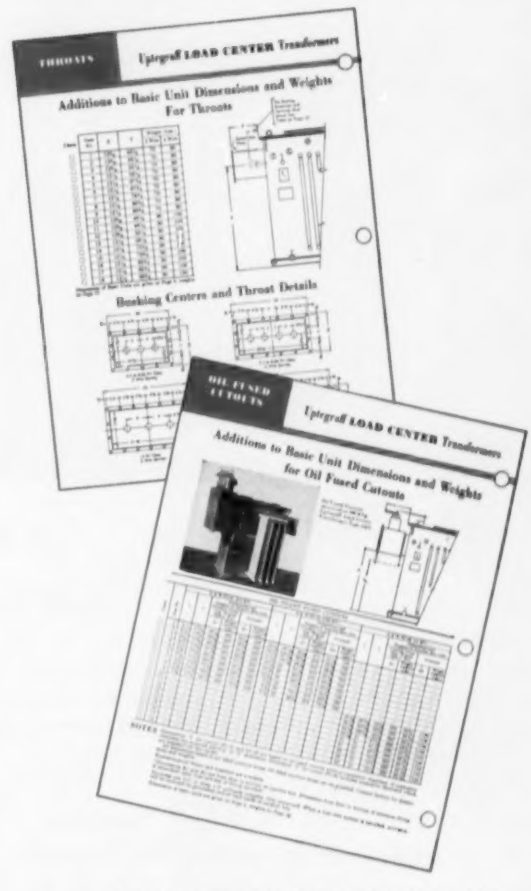


Engineering Design Data for

UPTEGRAFF

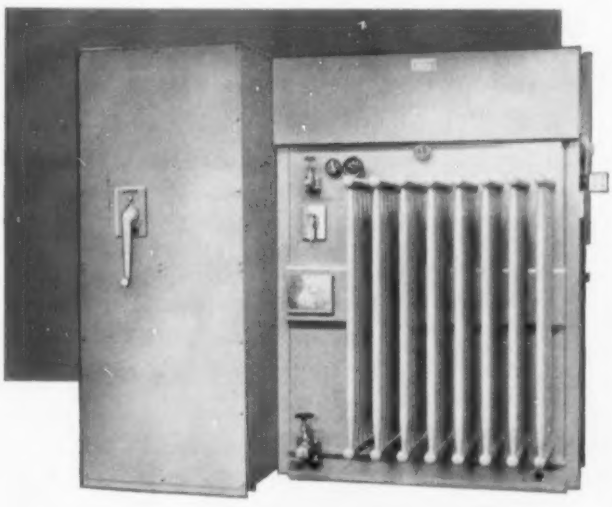
LOAD CENTER TRANSFORMERS

(150-2500 KVA)



Uptegraff announces a new series of *Liquid Filled* Load Center Transformers, made in eighteen ratings, from 150 to 2500 KVA., 3-phase. Designs are based upon extensive experience with this type of transformer, and represent modern engineering and manufacturing practice.

To simplify the selection and arrangement of auxiliary equipment, we have prepared a unique brochure, some pages of which are shown here. With this brochure, you can readily determine overall dimensions, total weights and other information for any combination of the Basic Transformer Unit with various types of switches and accessories. A check system permits the easy and accurate locating of desired data pertaining to various arrangements of properly rated equipment for any selected basic unit. We will be glad to send you a copy, free.



R. E. Uptegraff Manufacturing Co.
Scottdale, Pennsylvania

Send for a free copy of this 20-page data book, giving important and useful information on Uptegraff Load Center Transformers. Fill out and mail the coupon below.

R. E. Uptegraff Manufacturing Company
Scottdale, Pennsylvania

Please send a copy of your LOAD CENTER TRANSFORMER brochure, Catalog 132, to:

Name__________ Position__________

Company__________

Address__________

ECM

This could be you—"In the Land of No Distributors"

Who needs lamps at a time like this—ahead of eighty-eight missing items that are holding up the job... but it could happen to you if there were no distributors! You'd be forced to place orders direct with hundreds of different manufacturers located all over the country. Barring miracles, deliveries would be disorganized and a tangled mess.

What's more..."In the Land of No Distributors"—

- **You'd be pestered by an army of Manufacturers' Salesman.**
- **There would be no such thing as emergency "over-the-counter" service.**
- **You'd have to carry a tremendous inventory, and insure it.**
- **You'd go "telephone crazy" placing hundreds of calls a day to various suppliers miles away—to say nothing of the expense.**
- **Your Order Department and Accounting Department would have to be increased a hundredfold—and how about credit?**

It's different when you deal through distributors. You tap their inventories for all the equipment and supplies you need. You get it *all*—exactly *when* you need it. He's the *one* source for *everything* electrical—and he's *LOCAL.*

YOUR DISTRIBUTOR IS THE BEST FRIEND YOUR BUSINESS CAN HAVE!

It Must Be Right
The Trade Mark of TOP Quality
TRIANGLE
"IT MUST BE RIGHT!"

TRIANGLE CONDUIT & CABLE CO., INC.

NEW BRUNSWICK, NEW JERSEY

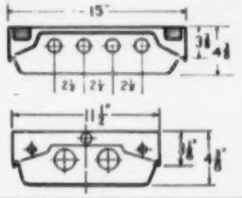
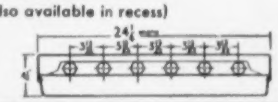
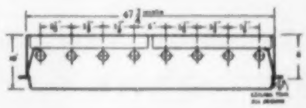
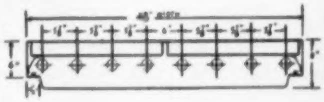
Manufacturers of Arteries for Electricity, Liquids and Gases

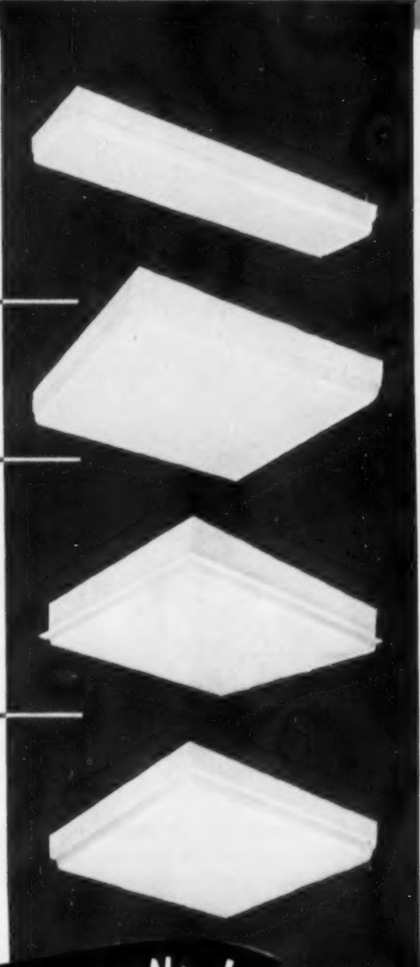
WIRE • CABLE • CONDUIT • PLASTIC PIPE • BRASS AND COPPER TUBE

Design Better Lighting Systems with Wm. PENN PLEXITONE*

. . . Fluorescent fixtures giving soft, shadowless lighting, yet with brightness and intensity. A new phase in unobtrusive diffused lighting, Plexitone fixtures, with plexiglass panels, "go" anywhere, offering new freedom in handling lighting problems.

All Wm. Penn lighting fixtures are made of 20 ga. prime steel throughout, die formed and welded. 350° baked white enamel finished inside and out with 85° reflectance. Adequate KO's for mounting and designed for simplified assembly.

No. 116 available in these models 116—240 —440 —240 R. S. (118v.) —440 R. S. (118v.) —248 S. L. (430 ma) —448 S. L. (430 ma) —296 S. L. (430 ma) —496 S. L. (430 ma)	**Electrical:** Quality white fluorescent lampholders with combination starter blocks. Glow-type starters included. Ballasts H. P. F., 118v., 60 cy. A. C. Also available with H. P. F. Rapid Start 118v., 60 cy. and Rapid Start 277v., 60 cy. E. T. L. Ballast.	**PLEXITONE No. 116** **1' x 4' surface unit** 
No. 117 available in these models 117—420 —620 —820 —420 T. S. (trigger start) —620 T. S. —820 T. S.	**Electrical:** Ballasts L. P. F. 118v., 60 cy. A. C., Standard or Trigger start. C. B. M. Certified H. P. F. also available with standard start Glow Type starters.	**PLEXITONE No. 117** **2' x 2' surface unit** (also available in recess) 
No. 120 available in these models 120—440 —440 R. S. (118v.) —448 S. L. (430 ma) —640 —640 R. S. (118v.) —648 S. L. (430 ma) —840 —840 R. S. (118v.) —848 S. L. (430 ma) —1040 —1040 R. S. (118v.) —1048 S. L. (430 ma)	**Electrical:** Quality white fluorescent lampholders with combination starter blocks. Glow-type starters included. Ballasts H. P. F., 118v., 60 cy. A. C. Also available with H. P. F. Rapid Start 118v., 60 cy. and Rapid Start 277v., 60 cy. E. T. L. Ballast.	**PLEXITONE No. 120** **4' x 4' Recess unit** 
No. 134 available in these models 134—440 —440 R. S. (118v.) —448 S. L. (430 ma) —640 —640 R. S. (118v.) —648 S. L. (430 ma) —840 —840 R. S. (118v.) —848 S. L. (430 ma) —1040 —1040 R. S. (118v.) —1048 S. L. (430 ma)	**Electrical:** Quality white fluorescent lampholders with combination starter blocks. Glow-type starters included. Ballasts H. P. F., 118v., 60 cy. A. C. Also available with H. P. F. Rapid Start 118v., 60 cy. and Rapid Start 277v., 60 cy. E. T. L. Ballast.	**PLEXITONE No. 134** **4' x 4' surface unit** 



ACCESSORIES:

#1A Twin-stem hangers and Canopy (10" centers) available in any length. 24" length is standard.

#2A Single-stem hangers and Canopy. #2A available in any length. 24" length is standard.

#2059 Flex Studs available to hold plastic dish in "hinged" position for easy maintenance. Plastic frames and yokes for recess hanging.

SOLD THROUGH WM. PENN DISTRIBUTORS

ENGINEERED LIGHTING

Wm PENN

FLUORESCENT LIGHT MFG. CO.

1429 S. 23rd St. • Phila. 46, Pa.

*® Wm. Penn Fluorescent Light Mfg. Co.

Mail Coupon Now!

Wm. Penn Fluorescent Light Mfg. Co.
1429 S. 23rd St., Phila. 46, Pa.

Gentlemen:

Please send free catalog

Name ____________________

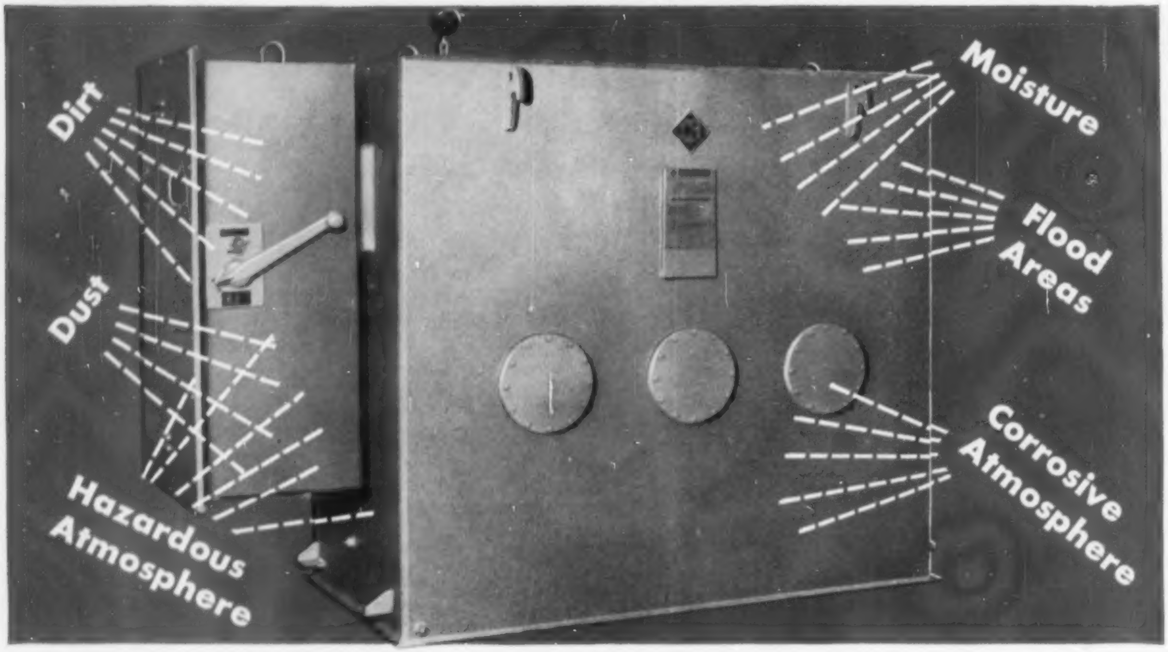
Company ____________________

Address ____________________

City ____________ Zone ______ State ______

ALLIS-CHALMERS
Sealed
Dry-Type
Transformers

Designed for the *Toughest Spot* In Your Plant



SAFE in any location regardless of Atmosphere or Moisture Conditions

Here's a transformer you can safely install anyplace without worries.

- **Fire or Explosion Hazard Eliminated** — Unit is hermetically sealed in inert-dry-nitrogen atmosphere.
- **Completely Protected**—Can be placed safely in flood areas, dirty and contaminated atmospheres, or in open work areas without vaults or barriers.
- **Insulation Life Increased** — Core and coil assembly is sealed in inert gas. Eliminating oxidation reduces thermal aging of insulation.
- **Maintenance Requirements Cut** — Elimination of cooling tubes and use of smooth tank surface reduce paint area as much as 60%. No internal liquids to maintain. All-welded construction. Number of gasketed openings reduced. Cleaning of core and coil eliminated. For these reasons, unit can be installed in hard-to-get-to places.
- **Low Installation Cost** — Unit is ready to be energized immediately upon delivery, after check to make certain no damage or leaks have occurred during shipment.

Allis-Chalmers transformers have an outstanding record of satisfying thousands of users all over the country. You can get the complete story on Allis-Chalmers sealed dry-type transformers from your local A-C office, or write Allis-Chalmers, Power Equipment Division, Milwaukee 1, Wisconsin.

A-C ALLIS-CHALMERS

A-5035

Product News

FOR MORE INFORMATION ON

NEW PRODUCTS
CATALOGS, BULLETINS
ADVERTISEMENTS

USE THESE CARDS

- **PRODUCT NEWS, PRODUCT BRIEFS:**
  Use first line of boxes. Insert item numbers of products on which more information is desired.
- **CATALOGS, BULLETINS AND ENGINEERING DATA:**
  Use second line of boxes. Insert item numbers of literature desired.
- **ADVERTISEMENTS:**
  Use third line of boxes. Insert page numbers of advertisements on which additional information is desired. Where more than one advertisement appears on the page, include the manufacturer's initials.

Please send me without obligation further information about the following: 5-56

Product News and Product Briefs, Item Number

Catalogs and Bulletins, Item Number

Advertisement on Page

NAME .... TITLE ....

COMPANY ....

ADDRESS ....

....

ELECTRICAL CONSTRUCTION AND MAINTENANCE — A McGraw-Hill Publication

NOT GOOD AFTER JULY 1, 1956

Please send me without obligation further information about the following: 5-56

Product News and Product Briefs, Item Number

Catalogs and Bulletins, Item Number

Advertisement on Page

NAME .... TITLE ....

COMPANY ....

ADDRESS ....

....

ELECTRICAL CONSTRUCTION AND MAINTENANCE — A McGraw-Hill Publication

NOT GOOD AFTER JULY 1, 1956

IMPORTANT...

- PLEASE PRINT LEGIBLY
- USE BLACK OR DARK BLUE INK
- DO NOT USE PENCIL OR RUBBER STAMP

Your Name and address will be reproduced and sent to the appropriate manufacturers. Illegible or incomplete addresses may result in your not receiving the information you desire.

ings from ¼ to 40 horsepower; at present are being engineered for individual applications.

Allis-Chalmers Mfg. Company, Milwaukee 1, Wis.

Bathroom Brackets (2)

New 14- and 15-watt trigger-start fluorescent bathroom brackets are equipped with G.E.'s new trigger-start ballast. Both the M-358 15-watt and the M-348 14-watt trigger-start fluorescents have canopy switches,

A new, improved BX armored cable employing thermoplastic insulation on the individual conductors. The insulation eliminates the need for braid on the singles, provides color-coding that goes all the way through, and makes stripping quicker and easier with no time wasted in trimming braid. The new cable is available in two, three, and four conductors in all standard sizes. It is listed by the Underwriters' Laboratories, Inc., and is rated 600 volts.

General Electric Co., Bridgeport 2, Conn.

PLACE 2¢
STAMP
HERE

The Editor
ELECTRICAL CONSTRUCTION AND MAINTENANCE
330 West 42nd St.,
New York 36, N. Y.

PLACE 2¢
STAMP
HERE

The Editor
ELECTRICAL CONSTRUCTION AND MAINTENANCE
330 West 42nd St.,
New York 36, N. Y.

Your Name and address will be reproduced and sent to the appropriate manufacturers. Illegible or incomplete addresses may result in your not receiving the information you desire.

FOR MORE INFORMATION ON

NEW PRODUCTS CATALOGS, BULLETINS ADVERTISEMENTS

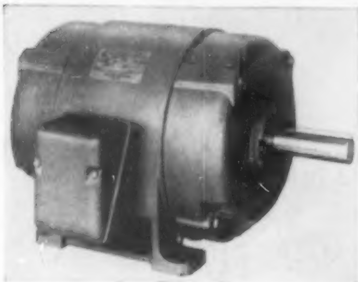
USE THESE CARDS

- **PRODUCT NEWS, PRODUCT BRIEFS:**
  Use first line of boxes. Insert item numbers of products on which more information is desired.
- **CATALOGS, BULLETINS AND ENGINEERING DATA:**
  Use second line of boxes. Insert item numbers of literature desired.
- **ADVERTISEMENTS:**
  Use third line of boxes. Insert page numbers of advertisements on which additional information is desired. Where more than one advertisement appears on the page, include the manufacturer's initials.

IMPORTANT...

- PLEASE PRINT LEGIBLY
- USE BLACK OR DARK BLUE INK
- DO NOT USE PENCIL OR RUBBER STAMP

Product News



Synchronous Motors (1)

A basically new synchronous motor, called the Synduction motor, has been developed. Unit combines the constant speed characteristics of the synchronous motor with the rugged construction, simplified maintenance and smaller size of the induction motor. It starts and accelerates like an induction motor; then, because of its high pull-out torque, it remains in synchronism and runs at constant speed regardless of load or line voltage fluctuations. Beyond the pull-out point, the unit runs as a squirrel cage induction motor. Unit is built on standard induction motor frames and enclosures; uses a simple die-cast rotor of the squirrel-cage type; requires no brushes, slip-rings, rotor windings or direct current excitation. It operates on a simple across-the-line starter. Motor output speed is directly proportional to applied frequency; the higher the applied frequency, the higher the motor speed. Constant speed applications of the Synduction motor are found in the food industry; on motor-alternator sets; frequency converters; packaging machinery. Adjustable speed applications are found in the synthetic fibre, plastic and paper industries. Other applications include; printing presses, glass industry, bristle cutting, wire drawing, automatic production lines. The new motor has been designed to operate over a wide frequency (up to 300 cycles and speeds up to 10,000 rpm) and wide speed range. Units are available in standard induction motor frames and enclosures in ratings from ¼ to 40 horsepower; at present are being engineered for individual applications.

Allis-Chalmers Mfg. Company, Milwaukee 1, Wis.

Bathroom Brackets (2)

New 14- and 15-watt trigger-start fluorescent bathroom brackets are equipped with G.E.'s new trigger-start ballast. Both the M-358 15-watt and the M-348 14-watt trigger-start fluorescents have canopy switches, run on 60-cycle ac current, and can be wired to a wall switch if desired. The M-359 and M-349, which are respectively the same as the M-358 and the M-348, are equipped with a convenience outlet. All metal parts are triple chromium-plated.

Moe Light Division of Thomas Industries, Inc., Louisville, Ky.

Switch Stations (3)

A new line of explosion-proof and dust tight standard duty EFS and heavy duty HEFS pushbutton and selector switch stations. The line is available in surface mounting types for control circuits of 600 volts ac maximum, for use in hazardous locations, Class 1, groups C and D. Both standard duty and heavy duty types are furnished in a variety of single and two element stations—single or double pushbutton, single selector switch, or single pushbutton and selector switch units. They are offered in either button operated or rocker arm actuated mechanisms. The rocker arm actuated types assure smooth, non-freezing operation under corrosive conditions. All interiors are interchangeable. They can be furnished in multi-gang and tandem units and in combination with other R&S EFS devices. Literature 2156-4 is available

Russell & Stoll Company, Inc., 125 Barclay St., New York 7, N. Y.

Armored Cable (4)

A new, improved BX armored cable employing thermoplastic insulation on the individual conductors. The insulation eliminates the need for braid on the singles, provides color-coding that goes all the way through, and makes stripping quicker and easier with no time wasted in trimming braid. The new cable is available in two, three, and four conductors in all standard sizes. It is listed by the Underwriters' Laboratories, Inc., and is rated 600 volts.

General Electric Co., Bridgeport 2, Conn.

Splicing Tape (5)

A new high voltage splicing tape, "Scotch" brand No. 23 electrical tape. Using a butyl rubber base, the new self-bonding tape is designed to meet the electrical and physical splicing needs of electrical contractors and utilities making high voltage splices. It possesses a high dielectric strength (650 volts per mil). It is intended for use as primary insulation on splices made on all insulated cables using ozone resisting compounds. After application, the tape fuses into a homogeneous mass, yielding maximum moisture resistance. It is recommended that the ¾-in. tape be necked down to ½-in. when wrapping to provide a good moisture seal and squeeze out possible air pockets. It has no corrosive effect on copper or silver.

Minnesota Mining and Manufacturing Co., 900 Fauquier St., St. Paul 6, Minn.

Fixture-Hanger (6)

A new explosion-proof and dust-tight flexible cushion fixture-hanger, designed to eliminate damage to fixture and stem assemblies while supporting loads up to 60 lbs. Action of high-strength brass bellows is aided by a stainless steel cushioning spring, to permit movement of fixture stem as much as 15 degrees from vertical in any direction. A set screw locks threaded stem in place. Stem assembly of this EFH fixture-hanger is designed so that it will not turn or twist the wires or connections. Unit meets NEC requirements for flexible support of pendant fixtures on rigid conduit stems longer than 12 in. Factory-assembled fixture-hangers with junction condulets are available in ½- and ¾-in. hub and fixtures stem sizes. Also available are separate fixture-hangers which mount on any of the CPS series from 20 condulets. These condulets, when assembled with fixture-hangers, are approved for Class I, Group C and D; Class II, Groups E, F, and G, and Class III.

Crouse-Hinds Company, Wolf and Seventh North Sts., Syracuse, N. Y.

Floodlight (7)

A new adjustable general purpose floodlight, Type ARC-20, is available for a wide variety of lighting applications, including industrial parking lots, storage and work areas, construction areas, railroad yards and decorative building lighting. Designed for use with 700-watt A-H18 or B-H18 mercury lamps or 1000-watt A-H15 mercury lamps, the unit is rugged and weatherproof. Maximum diameter is 20½ in. and overall length is 21½ in. Three types of heat-resistant glass lenses are available: flat, stippled-convex, and 40-degree-spread convex. Optional mounting brackets provide a choice of flat, slip-fitter, or clamp-base mounting.

Westinghouse Lighting Division, Edgewater Park, Cleveland, Ohio.

Tool (8)

A new tool has been developed to remove burrs, ream and bevel the cut end of thin wall conduit or Greenfield in one operation. It works on all sizes from ½-in. up. Called the "Hi" Ream-Rite, it has a plastic handle and two tool-steel blades, one longer than the other. To use it, one blade is inserted inside the conduit, the other stays outside. The difference in blade length is for the purpose of handling all EMT diameters from ½-in. up without binding. In ½-in. and ¾-in. sizes the longer blade goes inside; in 1-in. and larger sizes the shorter blade goes inside the EMT.

Holub Industries, Inc. Box 903, Sycamore, Ill.

Firm Alarm Unit (9)

Built-in automatic fire alarm protection for every room, basement, attic, garage, etc., is now available in standard unitized components ready to install as a "packaged" unit, to fit any size home or multiple building project. Master alarm unit is supplied with condulet housings to flush mount into the wall. Instrument panels are furnished in neutral gray tone or they may be finished to harmonize with any desired color

scheme. Receiver unit is generally placed in master bedroom and is completely assembled with built-in buzzer, transformer, terminals, etc. Additional alarm bells, gongs or buzzers may be wired into the system, which is of the safety closed-circuit type wiring and requires only 6 volts connection to thermostats and bells. Units can be flush mounted or plastered into wall or ceiling. Thermal cartridges can be replaced from front of assembly. Bulletin 511 is available.

Industrial Automation Corp., 2515 W. Montrose Ave., Chicago, Ill.

Batteries (10)

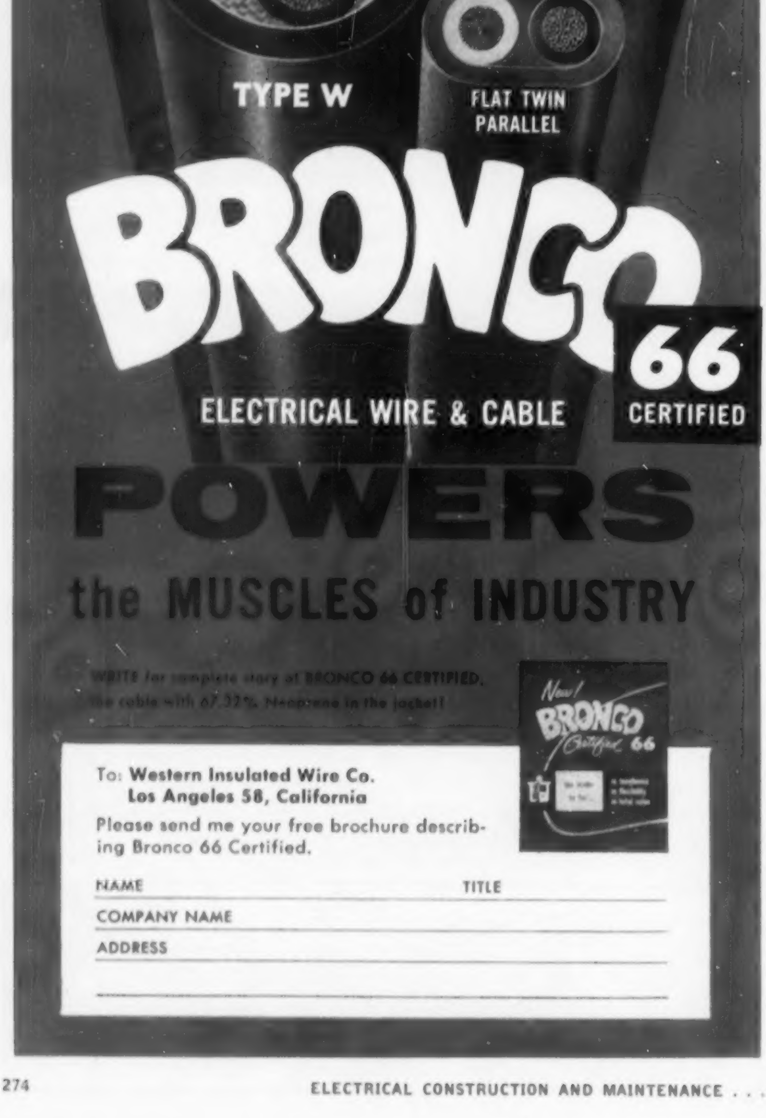
A new line of Exide-Manchex batteries, in heat-resistant polystyrene jars, are designed for stationary power applications in utility, telephone, railway and industrial plant operations. They retain the basic Plante positive plate. Some of the improvements are increased battery life; higher instantaneous discharge rates; reduced maintenance because of less frequent additions of water, more effective sealing, and easier cleaning; ready adaptability to cycle as well as float service. The new design jars and covers are made of heat resistant and shock absorbing polystyrene. Covers are sealed to jars and terminal posts to keep out dirt and prevent leakage of electrolyte. Large electrolyte reservoir at bottom of jar provides ample space between bottom of plates and jar to accommodate full amount of sediment whether it be in float or cycle service.

Exide Industrial Division, Electric Storage Battery Co., Box 8109, Philadelphia 1, Pa.

Motor Capacitors (11)

New high-capacity motor capacitors, Types KNT and KXT for ac applications. Type KNT is encased in a deep-drawn, no-seam, solderless terne plate container with base dimensions $4\frac{9}{16}$-in. by $2\frac{7}{8}$-in. Type KXT comes in a slim, extra-deep-drawn, no-seam terne plate case with base dimensions $2\frac{3}{16}$-in. by $2\frac{1}{4}$-in. and case heights up to $7\frac{3}{8}$-in. maximum. Both types are ideal for motor-running applications in split-phase motor circuit such as in air conditioning and refrigeration equipment, voltage regulators, fan motors, business machines. They may be used also in power-factor improvement and for general purpose ac applications. The terminal structure is leak-proof and compression-sealed, with phenolic cup insulators and fork-lug terminals. Quick-connect terminals—single or double blade type—in lieu of fork-lug variety, are also available for instantaneous connection of capacitors without soldering. Bulletin 178 is available.

Cornell-Dubilier Electric Corp., South Plainfield, N. J.



Meter Socket **(12)**

Recent developments in watthour meters allow accurate metering on services up to 200 amps with current passing directly through the meter. This eliminates the cost of meter transformers and their cabinet. Type S socket has been designed specifically for this new application. It has a 200-amp continuous rating without overheating and is available with full rated circuit closers. Lay-in type lugs accept up to 300 MCM wire. Current-carrying jaws are silver plated and spring loaded. Enclosure is available for surface or semi-flush mounting for plaster-stucco, woodsiding or brick veneer construction.

Square D Company, 6060 *Rivard St., Detroit* 11, *Mich.*

Motors **(13)**

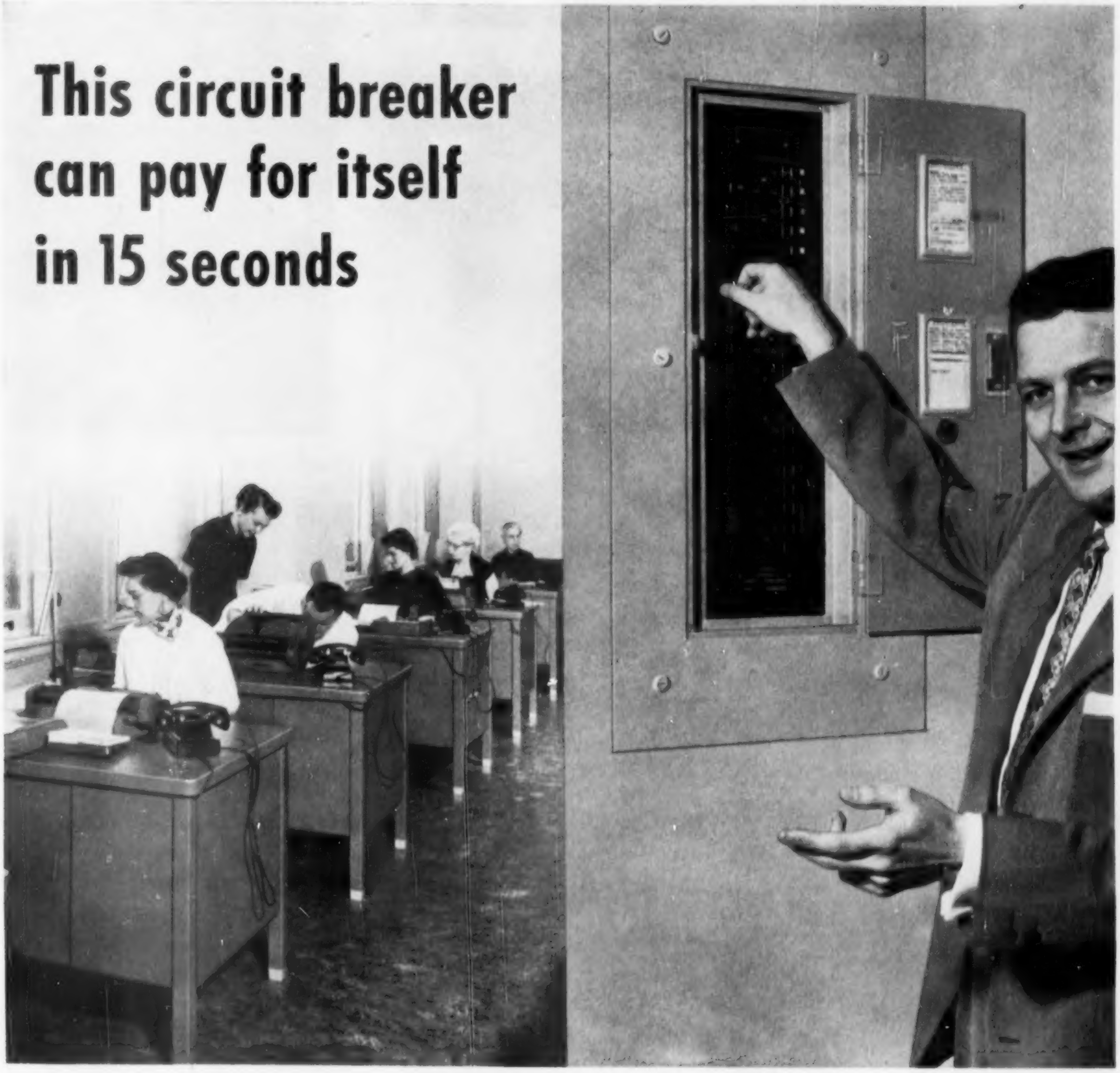
A new line of "Linc-Weld" motors with extruded plastic insulation. They are available in standard sizes from 1 to 40 hp, and built in the open type frame and torque design B. They comply with NEMA specifications. The new thermosetting plastic insulation is molded into and around the stator winding. The motor stator is placed into a die and the plastic material is forced into the die under the proper heat and pressure. The liquid plastic resin is extruded through the stator slots, covering the stator winding. After the plastic resin "sets", the stator is removed from the die.

Lincoln Electric Company, Cleveland 17, *Ohio.*

Induction Regulators **(14)**

Two new induction regulators, termed RM (repetitive manufacture) have been announced. The new, oil-filled induction units employ standardized designs and mass production methods. They utilize an improved winding method which increases insulation life, and reduces the size of the rotor assembly. The 125-kva, 2500/5000-volt RM unit supplants seven old ratings from 62.5-kva to 125-kva, at savings ranging from 1% to 32%. The 114.3-kva, 7620-volt RM

This circuit breaker can pay for itself in 15 seconds



Snap! And the power is on again. It's that simple with a Westinghouse AB De-ion® circuit breaker. Unlike other protective devices, it quickly restores power with just a simple flick of the finger—no valuable time wasted looking for fuses, no fuse replacement costs, no need even to call a maintenance man. The trip position of the breaker handle quickly identifies the affected circuit.

Today's buildings—with a wide range of electrical equipment from fans to floodlights—require positive insurance against overloads and short circuits. And when overloaded circuits go dead and business stops cold, that's when Westinghouse circuit breaker protection pays for itself many times over by restoring electrical service quickly, effortlessly—with practically no loss of valuable time.

When you consider circuit protection for today's buildings, it will pay you (and your clients) to specify Westinghouse AB circuit breakers. Your Westinghouse representative can offer you a complete range of circuit breakers for every application. Call him, or write to: Westinghouse Electric Corporation, P.O. Box 868, Pittsburgh 30, Pennsylvania. J-30193

WATCH WESTINGHOUSE!

*WHERE **BIG** THINGS ARE HAPPENING FOR **YOU***

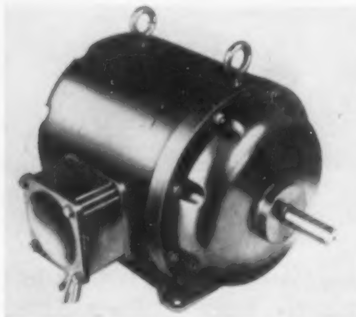
unit replaces two previous 114.3 and 76.2 kva ratings.

General Electric Co., Schenectady 5, N. Y.

Outlet Box **(15)**

The first of a series of fiber glass outlet boxes, No. 9314-C "FRP" octagon box, is fully insulated eliminating the need for grounding on many circuits. "FRP" has an arc resistance of 180 seconds and is not affected by moisture. Corrosive atmosphere, such as encountered in barns and certain industrial locations, will not attack it. It will withstand high operating temperatures and is fire resistant. It is available with standard round knockouts. Boxes are furnished with or without internal clamps. The material and application are listed by Underwriters' Laboratories.

Porcelain Products, Inc., Findlay, Ohio



Explosion-Proof Motor **(16)**

A new line of explosion-proof motors through NEMA frames 405 and 215. They meet the requirements for hazardous locations: gaseous, explosive dust, and explosive grain dust. Motors are specially treated to resist moisture, dust and corrosive atmospheres and feature extra long flame paths at shaft and bracket fits. Motors are available in standard, geared, or variable speed models, with optional mounting to meet individual requirements.

Sterling Electric Motors, Inc., 5401 Telegraph Road, Los Angeles 22, Calif.

Product Briefs

(17) Mathias Klein & Sons, Chicago, Ill., now offers an improved spring **plier** utilizing a coil spring just below the hinge. . . . (18) A portable **drafting machine,** called the Draftette, which clamps to the drawing board or sketch pad, is made by David Miller & Associates, Beverly Hills, Calif.

(19) A series of acid organic type chemical **wire strippers** have been developed by the London Chemical Company, Inc., Melrose Park, Ill. . . . (20) A **right-angle attachment**, No. 568, for air- and electric-driven impact wrenches has been announced by the Thor Power Tool Co., Aurora, Ill. . . . (21) General Electric Company, Syracuse, N. Y., has announced a new two-way radio communication equipment **cabinet** for housing transmitter, receiver and power supply chassis at a fixed location.

(22) A new "Tuffex" dual-purpose electric radiant **heating cable** has been developed by Everwarm, Inc., Knoxville, Tenn. . . . (23) A complete new line of handy **box covers**, developed to meet the requirements of every handy box installation, has been announced by Keystone Manufacturing Co., Center Line, Mich. . . . (24) The Gen-A-Matic Corp., Van Nuys, Calif., has added two new lightweight **generators** to its line of portable and standby electric plants.

(25) Bloomfield Tool and Gauge Co., Pontiac, Mich., has developed a new ladder type **hoist**. . . . (26) The Art Metal Company, Cleveland, Ohio, has developed a recessed Amcolens, which is made of clear glass prisms, and installed in Eliptisquare **lighting units**. . . . (27) General Electric Co., Schenectady, N. Y., has added to its line of butyl-molded **instrument transformers** a 600-volt window-type for switchboard and switchgear applications.

(28) Phaostron Instrument and Electronic Co., South Pasadena, Calif., has announced a new line of 3½-in. rectangular custom **meters**. . . . (29) Pioneer Signalite Co., a division of Angelus Aircraft, Inc., Los Angeles, Calif., has introduced a "Big-Flash" construction **warning light**, capable of 2100 hours of continuous operation on one dry-cell battery. . . . (30) Interchangeable **terminal blocks** with aluminum current-carrying parts have been introduced by the Wama Company, Baltimore, Md.

(31) Kaar Engineering Corp., Palo Alto, Calif., has developed a new and small low power industrial **radio telephone** specifically designed for installation on materials handling trucks, messenger vehicles and transportation units. . . . (32) A momentary contact **switch** in two models, rated for 6 amps at 125 volts or 3 amps at 250 volts is announced by the McGill Manufacturing Co., Inc., Valparaiso, Ind.

When Your Plans Call For FITTINGS & SWITCH BOXES

Specify

Arrolet CORPORATION

"Like money in the bank"— That's what estimators think about Arrolet's dependability when figuring job costs. Arrolet products have all the features you need to help keep installation time and costs under tight control.

Here's a good example:

New! ARROLET Bevel Corner

SWITCH BOX

3" x 2" x 2¼"

cat. no. 160-NGBR

Non-Gangable

Outstanding features of this box are the self-gauging notches for quick, accurate alignment with ½" and ⅝" walls. Only 2 nails needed to hold it securely in place.

Has 2 cable K.O.'s in each end and one ½" K.O. in bottom. 2 CRS non-metallic cable clamps. Projection welding gives BR bracket maximum strength.

Complete details about various mounting devices for the 160-NG series given in our New Product Sheet No. 2c.

For boxes, fittings and accessories that do the job best, make sure to specify 'ARROLET' in your next order.

FREE

WALL CHART — Box guide for maximum number of conductors. Quickly identifies boxes & covers.

Ask for Latest Catalog, Too. Write for Both, Today!

ARROLET CORPORATION
MONTGOMERY, PENNA.

Sales Representatives & *Warehouse Stocks
BALTIMORE, MD. • CHARLOTTE, N.C. • *CHICAGO, ILL. • *CINCINNATI, OHIO • *DENVER, COLO. • DALLAS, TEX. • *LOS ANGELES, CALIF. • *MIAMI, FLA. • NEW YORK, N.Y. • NEWTON CENTRE, MASS. • *PHILADELPHIA, PA. • ROCHESTER, N.Y.

Contractors report saving $5 to $10 per job

Pat. applied for

Available in a full range of sizes from ½" through 4".

with Blackhawk Slip-Fitter Service Entrance Heads

Yes, many contractors have reported that Blackhawk Slip-Fitter Service Entrance Heads have saved them as much as $5 to $10 per installation. That's a good reason why it pays you to sell Blackhawk.

Installation of the Blackhawk Slip-Fitter Service Entrance head is easier and faster. That's because there are no threads to cut and cutting threads takes time . . . costs money. A Blackhawk slip-fitter head simply slips over any conduit and is held firmly in place with two set screws.

With a Blackhawk Service Entrance Head you will cut installation time to minutes. Simply cut the conduit to size at the job site, slip the head on and tighten two set screws. That's all there is to it. The Blackhawk Service Entrance Head is a strong, neat, single-unit frame. It's available in a full range of sizes from ½" through 4".

Specify B-I when you buy

Blackhawk Industries

BLACKHAWK INDUSTRIES
Dubuque, Iowa

CATALOGS and BULLETINS

(33) HEATERS AND CONTROLS. 3 Bulletins. GEC-1005G, 60 pages, gives a complete listing of industrial heating equipment. Electronic induction heaters are described in 8-page GEA-6388. Off-peak control of water heating loads is the subject of 12-page bulletin GEC-981A.

(34) DISTRIBUTION TRANSFORMERS in sizes 167 kva and below are discussed in 8-page bulletin CS-201. Kuhlman Electric Co.

(35) MOTORS. Bulletin 1800 includes illustrated discussion of design and construction features of rapid-reversing motor capable of more than 200 idle reversals per minute. Louis Allis Co.

(36) CABLE SUPPORTS. Bulletin 156-E, 12 pages, covers cable ladder system design and accessories. Cabletrof, a large mesh trough system, is similarly discussed in 12-page Bulletin 256-E. P-W Industries, Inc.

(37) RESIDENTIAL LIGHTING of both traditional and modern design is presented in a well-illustrated full-color bulletin of 44-pages including many new designs. Globe Lighting Products, Inc.

(38) ELECTRICAL TAPES. 12-page Form 74-10-50 lists physical and electrical characteristics of rubber and friction tapes in both regular and ASTM grades; also plastic tapes and vinyl insulating tapes. Johns-Manville Dutch Brand Div.

(39) FLUORESCENT BALLAST bulletin GEA-6249, 20 pages, contains descriptive information on sound rating system, life expectancy, design features and selection. General Electric Co.

(40) EXPLOSION-PROOF MOTORS of ventilated and non-ventilated styles are described in 4-page Folder 189-25M-156 which includes cutaway drawings. Sterling Electric Motors.

(41) DISTRIBUTION EQUIPMENT. Catalog GEC-1032A, 160 pages, contains complete listing of panels, safety switches, wireways and busways, controls centers and substations. Trumbull Components Dept., General Electric Co.

(42) ELECTRONIC AIR CLEANER for commercial and industrial applications is described in Booklet B-1425. Westinghouse Sturtevant Div.

(43) LIGHTING. Sales problems in hardware stores as they relate to lighting are covered in 12-page booklet. Sylvania Electric Products Inc.

(44) DISTRIBUTION TRANSFORMERS in ratings from 480 volts to 15 kv are detailed in 32-page Bulletin 3-500. Transformer Div., Federal Pacific Electric Co.

(45) WINDOW FANS. Complete specifications and dimensions of the manufacturer's line are given in new 4-page booklet. Frigid, Inc.

(46) MOTOR STARTERS. Bulletin GEA-6358, 8 pages, gives new application information on CR 1061 and CR 1062 manual starters for motors up to 7½ hp. General Electric Co.

(47) CAPACITORS for air conditioning equipment, split-phase, capacitor-run motors and general purpose applications up to 440 volts. Bulletin 178, 2 pages. Cornell-Dubilier Electric Corp.

(48) MAINTENANCE of protective relays is discussed in 4-page Data Sheet 156UB. Multi-Amp Corp.

(49) PORTABLE POWER PLANTS. Folder MV-1205, 4 pages, tells how to select the proper plant for temporary power on construction jobs. Master Vibrator Co.

(50) OUTDOOR SWITCHES in 400-, 600- and 1200-amp ratings at 7.2 to 115 kv are for single-pole disconnecting applications. 6-page booklet 5601. Delta-Star Electric Div., H. K. Porter Co., Inc.

(51) ELECTRIC OVEN SECTIONS for industrial applications are described in two bulletins. Forms 55-104 and 55-105. Fostoria Pressed Steel Corp.

(52) ELECTRICAL TAPES. Brochure P6-1, 4 pages, lists complete line of insulating tapes with physical and electrical characteristics, applications, and availability. Kendall Co.

(53) LIGHTING FIXTURES for New York's Coliseum are detailed in 4-page folder giving features of luminaires' construction and actual application considerations. Frink Corp.

Reader's Quiz

QUESTIONS from readers on problems of industrial equipment, installation, maintenance and repair. Answered by electrical maintenance engineers and industrial electrical contractors out of their experience. For every question and every answer published we pay $5.00.

Transformer Current And Voltage Dips

QUESTION V29—A 3-phase transformer (75 kva-440 primary) is energized by a contactor in the primary to control furnace temperature. I believe high inrush magnetizing currents are the cause of lamp flicker on other parts of our 1200 kva distribution system. How can the effects of high inrush currents be minimized?—G.F.

ANSWER TO V29—A contactor throws the full load on at one time, so you have a sudden voltage change. With a saturable reactor or another system of getting 75 steps and throwing on the line one step every second and removing the load the same way you will get the effect of throwing on the line 1 kva at a time instead of 75 kva. The contacts will last longer.—H.S.

ANSWER TO V29—It is possible that this furnace load is causing the light flicker on starting, since this one load is about 6% of your total capacity. One way to help this situation is to install the contactor controlling the load on the secondary side of the transformer, thereby leaving the transformer energized all the time. The secondary contactor would be more expensive due to heavier current, but it might be worth it.—E.A.M.

ANSWER TO V29—It is standard practice to install step starters or contactors to prevent lamp flicker. A contactor with two or three steps would greatly reduce lamp flicker, the number of steps necessary being dependent upon the drop in voltage now indicated.

The best results can be obtained by installing a contactor having carbon piles as resistance. Carbon discs are compressed gradually preventing any noticeable change in voltage. If the contactor is installed in the secondary circuit of the transformer, the magnetizing current would be constantly established in the transformer and the power component of the total current would cause less lamp flicker when the load is connected.—B.A.S.

Potential Circuits and Current Circuits

QUESTION W29—Please distinguish between a potential circuit and a current circuit as used in control work. Why must current circuits be short-circuited and what process is used to de-magnetize a current transformer that has been accidentally opened?—J.B.K.

ANSWER TO W29—Potential circuits and current circuits are derived respectively from potential transformers and current transformers, the primary windings of which are connected across the line whose voltage is to be measured in the case of potential transformers, and in series with the line whose current is to be measured in the case of the current transformers. Each has a dual purpose: (1) To insulate instruments and meters from line voltage, and (2) to transform line voltage and current down to ratings of standard instruments.

The function of some instruments or relays served by circuits derived from instrument transformers, is to operate in proportion to the magnitude of the voltage or current, in which case phase position or direction of flow is inconsequential. In other more complex instruments or relays, the function is governed by the interaction of two currents.

Current transformer secondaries should be short-circuited before removing its associated instruments or relays because an extremely high voltage, frequently dangerous, develops in an open-circuited secondary. When the secondary is open, the entire primary current becomes a magnetizing current which induces the excessive voltage in the secondary.

Unless the transformer is ruptured or otherwise physically damaged, it is, as a rule, not liable to permanent loss of accuracy because

of an accidentally open-circuited condition.—W.R.S.

ANSWER TO W29 — When the word "potential" is used to describe a coil, it means that that coil may be connected across the full voltage or potential of that circuit or portion of the circuit. A potential coil usually has a large number of turns of fine wire, while on the other hand a "current" coil has comparatively few turns of much larger wire. A current coil is always used in series with the other components of its circuit. It therefore carries the full current which is being fed to the components of its circuit.

The secondary winding of a current transformer must always be kept with a closed circuit primarily for safety reasons, although the insulation of the transformer may be punctured if an open circuit condition exists for many seconds. The core is generally magnetized or "biased" after an open circuit condition. When the secondary of a current transformer is open-circuited while energized, the current transformer immediately becomes a step-up transformer with the secondary winding as the high voltage side. The voltage induced in the secondary winding is proportional to the primary current. In addition, the primary current excites the core to saturation which allows the maximum voltage to be induced in the secondary winding. The impedance of the secondary under open circuit conditions is very small compared to its impedance under normal closed-circuit conditions.

To maintain control accuracy, open-circuited current transformers should be demagnetized before reuse.

A current transformer which has undergone open-circuit conditions and has assumed a magnetic bias may be demagnetized as explained below.

Disconnect the primary from its circuit. Connect the secondary winding to a 115-volt, 60-cycle source, which is in series with a rheostat of sufficient size to be able to vary the secondary current from a maximum of 7 amps down to the minimum current which the rheostat will permit (1 amp or less). This circuit should also be fused to 8 amps. With the rheostat, vary the current from minimum to maximum slowly, ten or twelve times. This operation should remove the magnetic bias from the current transformer; however it may have to be repeated.—W.E.N.

Type Motor for Chain Hoist

QUESTION X29—A chain hoist is 15 tons, hand powered, with movement of approximately 70 ft. The power head is a 9 to 1 gear box which will turn the endless chain of the hoist. Should the motor to power the gear box be a variable speed, constant hp or meet some other requirement? Is there a rectifier on the market so that a dc motor could be used from the ac current available on the site?—E.S.H.

ANSWER TO X29—For a lifting speed of 30 ft per minute a 25 hp motor would be about right. This hoist could be powered either by a slip ring induction motor directly from the ac power supply, or a variable speed dc motor through a rectifier, as you suggest. All the major electrical manufacturers have rectifier "package jobs" designed for just such service. A variable speed, constant horsepower motor would be best for this service. If the hoisting and lowering is usually done at full speed an ac slip ring induction motor would probably cost less, have less maintenance, and do the job satisfactorily. The extra cost of the dc motor and rectifier would be justified if hoisting and lowering are to be done at various speeds, and if the extra flexibility of dc dynamic braking on lowering is needed.—E.A.M.

ANSWER TO X29—for a small chain hoist of the type described, a slip ring induction motor of suitable horsepower rating would suffice. However there are limitations as to the feasibility of an induction motor when considering the accuracy of control and the power demands. Should there be a demand for more accurate control of the system more reliable automatic slowdown demands and better overall response, a direct connected dc motor would be most practical. There are suitable rectifiers of sufficient capacities for such use so that the ac supply could be utilized should the system require a dc motor application. All factors being considered, an induction motor could be used for this installation with certain restrictions and limitations. However the dc motor would be much more efficient.

Combination rectifier and dc motor assemblies for hoist applications are available from manufacturers.—J.B.K.

Fluorescent Lamps And Light Output

QUESTION Y29—Which gives the most light, a 48-in. starter type fluorescent lamp or a 48-in. instant start slimline? Which is the most economical, all factors considered? —*D.H.N.*

ANSWER TO Y29—Although the 48-in. starter-type or preheat fluorescent lamp does give a little more light than a 48-in. slimline, the difference (see latest lamp data bulletin for actual lumen ratings) is not too significant. The need for a few more lamps to do a given job, resulting from about seven percent light output difference, is certainly justified in some cases by the advantages of instant starting and no starter troubles. However, from a strictly dollars and cents standpoint, the starter-type will usually prove less costly when you consider all the pertinent factors, such as original equipment cost, original and replacement lamp costs, operating costs, and maintenance costs. But a cost comparison study would seem incomplete if it did not include the newer rapid start lamps. Light output is the same as that of starter-type lamps. Lamps start almost instantly, no starters are used, rated average lamp life is the same as that of the starter-type, and equipment costs are similar. Where 48-in. lamps are desired, I think a cost study of the three lamp types will reveal a strong case for rapid start.—C.H.C.

Can You ANSWER These QUESTIONS?

QUESTION J30—How does a drop in voltage affect the amperage in ac motors? It is known to me that the power of a motor is directly proportional to the square of the voltage with limitations.

Now I am interested to learn how the amperage will change if voltage decreases or increases, the motor being connected to a constant load. In this connection I realize that the current will rise as the motor comes to a standstill if the power required becomes larger than the power supplied by the motor.

I hold the opinion that the amperage will decrease as voltage drops as long as the motor keeps running. Other people maintain the current will go higher in drop of voltage as the power wanted re-

mains constant. They furthermore say that the reading of an electric kilowatthour meter went up as a result of low voltage; the utility company, realizing this fact, refunded money to the customer.—S.P.M.

QUESTION K30—We have two 1250 kva, 1200 rpm alternators in our plant. What could cause brush imprints on the surface of the same ring, regardless of polarity? Machines are serviced monthly and rings polished. The imprints are at a different place each time.—T.W.D.

QUESTION L30—Can you tell me where or give me proper information on the following. Running a 3-phase line and a 110-volt line in the same conduit. Also low voltage fire alarms in conduit or not. These have been brought up by different electricians. However, to this date I have not permitted it and would appreciate being brought up to date.—A.J.C.

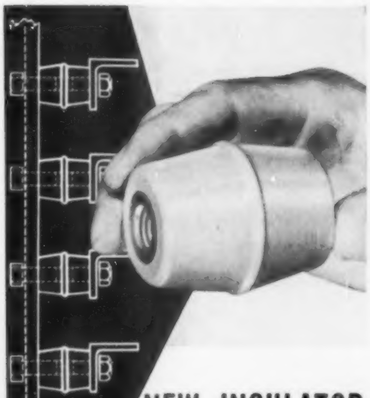
QUESTION M30—We have experienced faulty operation of the thermal overload trips in our motor starters. At times they have failed to trip on overload, resulting in motor burnouts. Can anyone suggest a convenient test method that can be used by an electrician in the plant to check these devices periodically.—R.E.B.

QUESTION N30—We have 3-phase, 440 volts, 60-cycle, 10-3 hp, 14-4.5 amps, squirrel cage induction motor. The stator has two separate windings for slow and fast speeds connected series star and 2-parallel delta respectively.

On test for fast speed we found out the starting current to reach approximately 80 amps and the phase currents are unbalanced. We rewound the stator with exceptional care, but the resulting condition is still the same. We believe the trouble to be in the rotor, but since the bars, end rings, and fans are a one-piece aluminum casting, we have our doubts as to the rotor's destructibility.

What is the correct procedure in testing the rotor for good condition, and explain the "why" and "how" the stator is affected when the rotor is defective?—L.V.

PLEASE SEND IN YOUR ANSWER BY JUNE 15



NEW INSULATOR FOR TRAVELING CRANE TROLLEY FEEDER CONDUCTORS

Cuts Installation Costs 56%

Red Seal's new polyester "504 insulators" are replacing hardwood conductor posts on trolley feeder runways at tremendous cost savings. One example, the installation sketched here, cost $8.80. It replaced a conventional installation of hardwood conductor posts and spacers costing $20.00.

The "504 insulator" is made of polyester, reinforced with fiberglass, and is practically indestructible in regular heavy duty use. Two tapped inserts of cadmium plated, machined steel make installations easy—yet will not pull, vibrate or turn loose.

Fiberglass reinforcement gives high tensile, compressive and cantilever strength, as well as excellent impact resistance. Polyester binding material makes insulator resistant to moisture, dirt, corrosion, electrical arc and heat.

Designed for service to 1000 volts, the "504" is the smallest insulator available, measures only 1⅞" dia. by 2¼" long. Each insulator, is carefully inspected and tested at 10,000 volts before shipment.

For full details, write today

RED SEAL ELECTRIC CO.

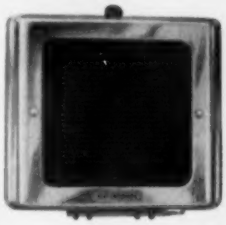
6321 Detroit Ave. • Cleveland 2, Ohio

ONLY *ELECTROMODE* *Offers so much!* in Automatic ELECTRIC HEAT

ALL YOUR REQUIREMENTS FROM ONE RELIABLE SOURCE
COMPLETE OR SUPPLEMENTARY HEAT

FOR HOME . . . .

- √ **BASEBOARD HEATERS** *Low-Level Perimeter Heat*
- √ **WALL-TYPE AND PORTABLE** *Fan-Circulating Models*
- √ **PANEL HEATERS** *Radiant Convection*
- √ **RADIANT CABLE HEAT**



WALL MODEL
For bathroom or small room.

FOR INDUSTRY . . . . . .

- √ **SUSPENSION-TYPE**
- √ **PORTABLE AND SUSPENSION**
- √ **EXPLOSION-PROOF**

SUSPENSION-TYPE
Solves hard-to-heat areas in the plant and isolated locations.

ONLY *ELECTROMODE* has the SAFETY-GRID

a completely sealed-in CAST ALUMINUM HEATING ELEMENT. All electric wires are insulated and embedded within this finned aluminum casting. Absolutely no exposed hot wires or glowing coils, and no danger of fire, shock or burn. It's the greatest feature any electric heater ever had and it is guaranteed for five years.

Around The FARM . . .

- √ **MILK HOUSE HEATERS**
- √ **PUMP HOUSE HEATERS**

MILK HOUSE HEATER
Also useful for brooder pens, fruit and vegetable bins, etc.

***ELECTROMODE* INSTALLATIONS BENEFIT CONTRACTOR AND USER**

- Full Range of Designs and Sizes for every need.
- Automatic Room Temperature Control.
- Quality Line—Made by Experienced Manufacturer.
- No Call Backs—No Servicing—No Adjustments.
- Easy to Install—Saves Time and Labor.
- Profitable Line to Handle.

ELECTROMODE
Division of
COMMERCIAL CONTROLS CORPORATION

Dept. EC-56 45 Crouch St., Rochester 3, N. Y.

Please send FREE Electric Heating File, containing specifications, illustrations, installations, prices and how to figure electric space heating. We are interested in:

☐ Home and Office Heaters ☐ Industrial Unit Heaters ☐ Farm Heaters

Name ____________________

Address ____________________

City ____________________ Zone ______ State ______

Cutler-Hammer Service Control
Tops in economy without compromise

Smart contractors everywhere are saying, "I never compromise when I install service control—I use Cutler-Hammer, it's tops at no extra cost . . . exactly the right type of unit for each job, never a makeshift substitute".

Standardize on C-H service control and you insure uniformity of installation, uniformity of performance, and uniformity of customer satisfaction. Every member of the Cutler-Hammer Service Control family is manufactured to meet the same standards of quality motor control. A host of plus features make C-H service control easiest to install, tops in performance and long life.

Cutler-Hammer's complete line of service control rules out compromise. There is the "perfect" type of service control available for each job . . . you install just what your job requires, nothing more, nothing less.

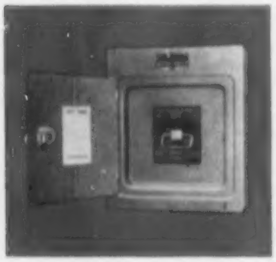
Your Authorized Cutler-Hammer Distributor carries a complete stock of this service control, you never need "shop" for the "perfect" type of a unit. A single source of supply . . . a reliable source of supply.

Let Cutler-Hammer Service Control help sell your service. Cutler-Hammer, nationally advertised in such magazines as *SATURDAY EVENING POST, TIME, NEWSWEEK*, etc. is recognized by all as a manufacturer of quality products. Don't build "sales resistance" by using an unknown brand . . . standardize on CUTLER-HAMMER, a name respected by your customers.

C-H service control is tops in economy . . . priced with the lowest—quicker and easier to install, you spend less time on the job—works better and lasts longer, you make fewer service calls.

Standardize on Cutler-Hammer Service Control—either fused or breaker type. For further information see your Authorized Cutler-Hammer Distributor today. CUTLER-HAMMER, Inc., 1306 St. Paul Avenue, Milwaukee 1, Wisconsin.

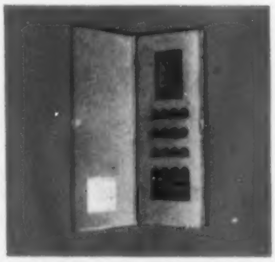
CUTLER-HAMMER
SERVICE CONTROL
C-H



4333 Line—One 60 Ampere pull-out. Up to 8 plug fuse circuits. Surface and flush mounting. NEMA 1 and NEMA 3 enclosures.

4334 Line—Two 60 Ampere pull-outs. Up to 8 plug fuse circuits. Series or parallel connected. Surface or flush mounted. NEMA 1 and NEMA 3 enclosures.

4335 Line—Three 60 Ampere pull-outs. Up to 8 plug fuse circuits. 60 Ampere water heater pull-out easily wired for separate metering. Surface or flush mounted.



4336 Line—100 Ampere main pull-out with two 30 or 60 Ampere branch pull-outs. Up to 16 plug fuse circuits. Surface or flush mounted. NEMA 1 and NEMA 3 enclosures.

Questions on the Code

Answered by

B. A. McDONALD, *New York Board of Fire Underwriters, Rochester, N. Y.*
GLENN ROWELL, *Electrical Engineer, Fire Underwriters Inspection Bureau, Minneapolis*
B. Z. SEGALL, *Consulting Electrical Engineer, New Orleans, La.*

Oil Burner Wiring

Q. *Will you please give me your opinion regarding oil burner installation wiring?*

I have been criticized for allowing oil burner electricians to use non-metallic cable within the burner compartment of a jacketed boiler. This compartment is adequately ventilated and it does not exceed the temperature limitation of TW insulation.

My confusion arises from the fact, that recently I have found TW wire is installed in Greenfield conduit on "Underwriters' Laboratories approved, factory wired boiler burner units."

This TW installation does not give the protection that non-metallic would, if it would accidentally get in contact with the ground.—E.A.G.

A. The maximum operating temperature of TW insulation is 60 C-140 F and when it operates in an ambient temperature of 60 C it cannot carry any current. If a No. 14 TW conductor operates in an ambient temperature of 50 C-122 F its current-carrying capacity is 8.7 amps. See Table No. I, Chapter 10. While the compartment in question does not exceed the temperature limitations of a TW conductor, it is evident from the foregoing that as the temperature approaches 60 C-140 F the conductor may carry little if any current without raising the temperature above 140 F. This 140 F limit concerns both the ambient temperature and also the temperature which results when the conductor carries current. In order to justify your opinion, I believe temperature readings should be taken during a cold spell when the burner operates for long periods of time due to the demands of the occupant. Such readings coupled with the current used would enable you to determine the heat to which the conductor insulation is subjected. Many factors are involved with the design of an oil-fired boiler and in the absence of definite temperatures which are involved, I would hesitate to accept type TW insulation within the burner compartment.

Insofar as the U. L. approved unit is concerned it is my opinion that the TW conductor installed as described in flexible conduit will not, when carrying the necessary current, reach a temperature in excess of 140°F. If it does, it would be in violation of the code. The U. L. however knows from tests, just what the temperatures are for the many different types of installations. They must decide the clearances from combustible surfaces. It is therefore questionable to compare a field installation with one that has been subject to the standards set up by U. L. I do not agree that a non-metallic cable installation gives more protection than a flexible conduit installation.—B.A.McD.

Wiring for a Service Station

Q. *We have recently been called back on a filling station job to move sealing devices inserted in conduit runs extending out to the pump island, the inspector claiming that these devices had to be 18 in. or more above the floor level in order to comply with the Code. In the past we have felt that by placing them as close to the floor line as we could, we could reduce the amount of condensation which would occur within the conduit runs out to these pump islands. Therefore we felt we were making a safer installation by locating these sealing fittings as near the floor as we could. Do you feel that this constitutes any appreciable hazard and is it a Code violation? —R.C.*

A. Actually the Code would permit the sealing fitting to be located on either side of the boundary where the conduit run passes from a nonhazardous location to a hazardous location. There-

fore, if the conduit run and sealing fitting in question is located in that portion of a filling station where automobiles are serviced or worked upon, Section 5120 defines that area within 18 in. of the floor as being a Class 1 Division 2 location and paragraph b.2 of Section 5015 states that each conduit run passing from a Class 1 Division 2 hazardous area into a nonhazardous area shall have a sealing fitting located on either side of the boundary of such hazardous area. It also states that where the sealing fitting is on the hazardous side of the boundary, the conduit between this sealing fitting and the nonhazardous area shall be without union coupling box or fitting to a point at which the conduit leaves the hazardous area and, furthermore, that this conduit shall be rigid conduit. Therefore, in my opinion the location of a sealing fitting just above the floor in the lubritorium area of a service station would not be a Code violation if rigid conduit is used between this sealing fitting and the distribution cabinet located higher on the wall. It is, of course, assumed that this distribution cabinet will be more than 18 in. above the floor level. —G.R.

Bus Plug-in as Motor Disconnect

Q. *I have several hundred machine tools of various types to wire up, using a bus duct feeder approx. 14 ft above the floor level. The various bus duct manufacturers tell me that one advantage of plug-in bus duct (400 amp) is that no disconnect switch is necessary on the machine tool, only the motor starters and pushbuttons. From the Code, I gather a different impression. The way I interpret the Code, a bus plug although having a switch and fuses is not suitable because it is ampere rated, and not horsepower rated. Also according to the Code, the disconnect switch must be readily accessible. The bus plug switch is not readily accessible, because it requires a ladder or a long pole to get to it and trip it.*

These machines will be installed in the city of Chicago, and from contractors and inspectors I get various interpretations. The majority say that they allow a bus plug switch as a disconnect, but I do not want to take a chance on having to go back later and install safety switches on all of the machines, if some one should decide

to enforce the Code the way I interpret it.

Please send your interpretation as soon as possible as I must install these machines in the next month or so.—R.E.R.

A. Section 4411 of the Code requires the disconnecting means for a motor and its controller to be readily accessible. Article 500 defines "readily accessible" as follows: "Capable of being reached quickly for operation, renewal, or inspection, without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc."

On November 13, 1942 Official Interpretation No. 236 was issued as follows:

QUESTION: Does the use of a portable hook stick eliminate the question of elevation, as contained in definition of word "accessible"?

QUESTION: Does the use of a portable hook stick satisfy the requirements of the definition of the words "readily accessible"?

FINDING: The use of switch hooks was not considered in drafting these definitions.

Section 3808 requires switches in general to be readily accessible insofar as practicable, and Section 2351 requires a service switch to be readily accessible.

Section 2435 requires an overcurrent device to be readily accessible except for busways.

A review of these Code requirements indicates to me that a bus plug switch located as described is readily accessible when a hook stick is provided for its operation and it appears apparent that the definition of "readily accessible" supports this opinion. When a hook stick is readily available, you do not have to climb over or remove obstacles or use a ladder or chair to operate the switch. The official interpretation on this point further indicates that this question was not considered of sufficient importance to promote a definite decision on this question, otherwise some action would have been taken during the 14 years which has elapsed since the date of the interpretation. Section 3808 recognizes some conditions where switches need not be readily accessible.

Section 4409 requires the disconnect switch for a motor controller to be located in sight from the controller location or be arranged to be locked in the open position. This provision would permit a motor disconnect to be located in the basement of a building with

the motor on the second or third floor. In such a case a motor disconnect located on a busway, provided with a hook stick, would be far more accessible for operation than a disconnect located in the basement. From a standpoint of the definition itself and the objective to be attained, as provided in Article 430, there is no question in my mind with respect to the use of a hook stick as a means for operating the disconnecting means for a motor.

Plug-in switches are available with hp ratings and of course plug-in devices may be circuit breakers.

This opinion of the wording and the intent of the Code is personal and, in the absence of a definite official interpretation, should be so considered. It is therefore very important that local inspection authorities be consulted with respect to their interpretation or local provisions which cover this question. It appears to me that Section 4411 should definitely answer this question.—B.A.McD.

Derating Conductors

Q. *We are connecting a number of switches and distribution cabinets with an auxiliary gutter run across horizontally below these cabinets and now the question has arisen as to whether or not our gutter is sufficiently wide to comply with the Code. We note under Section 3736 that where vertical conductors No. 1 or larger are run, minimum widths of gutters are shown. However, in our case the conductors are run horizontally in a horizontal gutter beneath the equipment and we question whether or not the Code requires a minimum size of such a gutter. Conductors we are using range in size from 500,000 CM down to No. 14's and at one point this gutter will contain 27 conductors. Does the Code provide a minimum width for such conductor and does Table No. 1 indicate the proper carrying capacities for the conductors within the auxiliary gutter?—K.P.*

A. The table in Section 3736 showing minimum widths of gutters applies to both vertical and horizontal runs. If you will note paragraph e. under Section 3749, you will find there it states "Where insulated conductors are deflected within the auxiliary gutter, either at the ends or where conduits, fittings or other raceways

enter or leave the gutter, or where the direction of the gutter is deflected greater than 30 degrees, dimensions corresponding to Section 3736 shall apply." Therefore, in a gutter in which the largest conductor is a 500,000 CM, it would be necessary that the gutter be not less than 6 in. in width.

In regard to the carrying capacity of the conductors within the raceway, at the present time Section 3745 contains a fine print note which states "The correction factors specified in Note 4 of Table 1 of Chapter 10 are not applicable." I am unable to explain why this fine print note is published in this section of the Code as experience has proven time and again that if conductors are not derated in auxiliary gutters and in wireways, it is perfectly possible to have them overheat to the point where they destroy their insulation. In fact, this has occurred in many instances and at the present time serious consideration is being given to requiring the derating of conductors contained in wireways or auxiliary gutters. I therefore would recommend that you derate conductors even though the Code does not make it mandatory at the present time. —G.R.

Scope of the National Electrical Code

Q. *In the Introduction to the National Electrical Code under Purpose and Scope, railways are specifically excluded where the equipment is used ". . . in the exercise of its function as a utility . . ."*

How would this apply to the following, assuming all are railroad owned and maintained by railroad electrical forces? Please give the authority or reasoning behind each opinion.

1—*Transportation yard facilities (floodlighting, yard offices, passenger car standby circuits, etc.).*

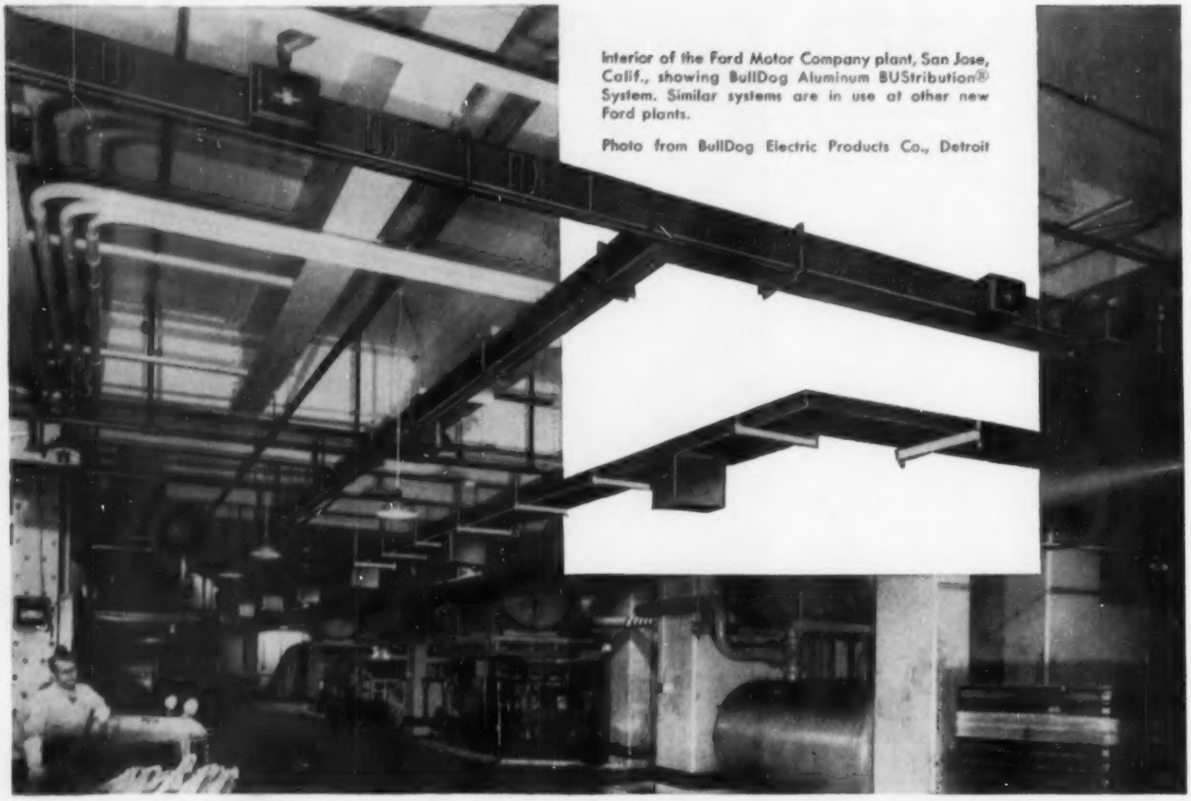
2—*Enginehouse facilities, including fueling stations, locomotive washing plants, interior building wiring.*

3—*General offices.*

4—*Leased warehouses (leased to outside parties).*

5—*Railroad owned and operated freight warehouses.—D.H.N.*

A. When this clause first appeared in the 1937 Code the following comment was given by A. B. Smith of NEMA who pre-



Interior of the Ford Motor Company plant, San Jose, Calif., showing BullDog Aluminum BUStribution® System. Similar systems are in use at other new Ford plants.

Photo from BullDog Electric Products Co., Detroit

FORD INSTALLS BUSWAYS USING 1,500,000 POUNDS OF ALUMINUM CONDUCTOR

Installation costs less, provides more power per pound of metal. System is more flexible and operates with no increase in voltage drop or temperature rise over comparable copper system.

Since 1951, Ford Motor Company has been equipping its new plants with aluminum bus distribution systems. These include plants at Detroit, Chicago, Buffalo, Cleveland, Louisville and San Jose.

By switching to aluminum, Ford diverted more than 3 million pounds of critical copper to other uses. And Ford acquired a distribution system at lower cost.

Because aluminum is lighter, Ford received more conductor per pound of metal . . . put less weight on the building superstructure.

Because aluminum costs less than copper, Ford received more conductor per dollar invested.

And these prefabricated conductors make a neat, safe, flexible installation that brings power to the job in any amount at any location. They can be readily moved to meet new power demands. Standard fittings, tools and methods are employed.

For more information on these modern packaged plant distribution systems, contact your nearby Alcoa sales office. Or write Aluminum Company of America, 2310-E Alcoa Bldg., Pittsburgh 19, Pa.

Your Guide to the Best in Aluminum Value

ALCOA ALUMINUM

ALUMINUM COMPANY OF AMERICA

THE ALCOA HOUR
TELEVISION'S FINEST LIVE DRAMA
ALTERNATE SUNDAY EVENINGS

EL. C. & M. SUBSCRIBERS!

WE'RE PUTTING FINISHING TOUCHES ON YOUR '56-'57....

INSIDE EPG ...

- A complete directory of manufacturers
- Trade name listings
- Manufacturers' product specifications
- Electrical calculations and symbols
- Lighting, heating, sound system data

Your new, revised EPG will reach you in mid-September, as a regular part of your subscription to ELECTRICAL CONSTRUCTION AND MAINTENANCE. A full year's work goes into it. Your EPG is designed specifically for electrical men—the only complete, verified reference on electrical apparatus and supplies . . . utilization equipment . . . components . . . tools and accessories, and allied products.

TURN THE PAGE FOR DETAILS . . . →

HOW epg's FOUR MAJOR

BUSWAYS

BullDog Electric Products Co., 7610 Joseph Campau, Detroit, Mich.
Continental Electric Equipment Co., Box 1055, Cincinnati 1, Ohio
Empire Switchboard Co., Inc., 810 Fourth Ave., Brooklyn 32, N. Y.
Federal Pacific Electric Co., 50 Paris St., Newark 5, N. J.
● GRAYBAR ELECTRIC CO., INC., 420 Lexington Ave., N. Y. 17, N. Y.—ADV. PG. 2
Gustaveson, Inc., 8600 Chestnut St., Kansas City 30, Mo.
Multi Electric Mfg. Inc., 4223 W. Lake St., Chicago 24, Ill.
National Electric Products Corp., Gateway Center, 140 Stanwix St., Pittsburgh 22, Pa.
Roller-Smith Corp., 1001 8th Ave., Bethlehem, Pa.
Royal Switchboard Co., Inc., 460 Driggs Ave., Brooklyn 11, N. Y.
Square D Co., 6060 Rivard St., Detroit 11, Mich.
Westinghouse Electric Corp., P. O. Box 868, Pittsburgh 30, Pa.
● WESTINGHOUSE ELECTRICAL SUPPLY CO., 40 Wall St., New York 5, N. Y.—ADV. PG. SECOND COVER

PRODUCT DIRECTORY

Approximately 1,600 specific products, listed alphabetically, with cross reference. Under each heading, manufacturers will be listed alphabetically, with names and complete addresses.

TECHNICAL DATA SECTION

Electrical symbols, diagrams, definitions, tables, formulae, and practical calculations used in electrical construction work. Includes sections on lighting layout and design . . . electric space heating . . . sound systems . . . National Electrical Code tables . . . conversion tables and circuit calculations.

DATA ON TYPICAL FLUORESCENT BALLASTS
Used for General Lighting

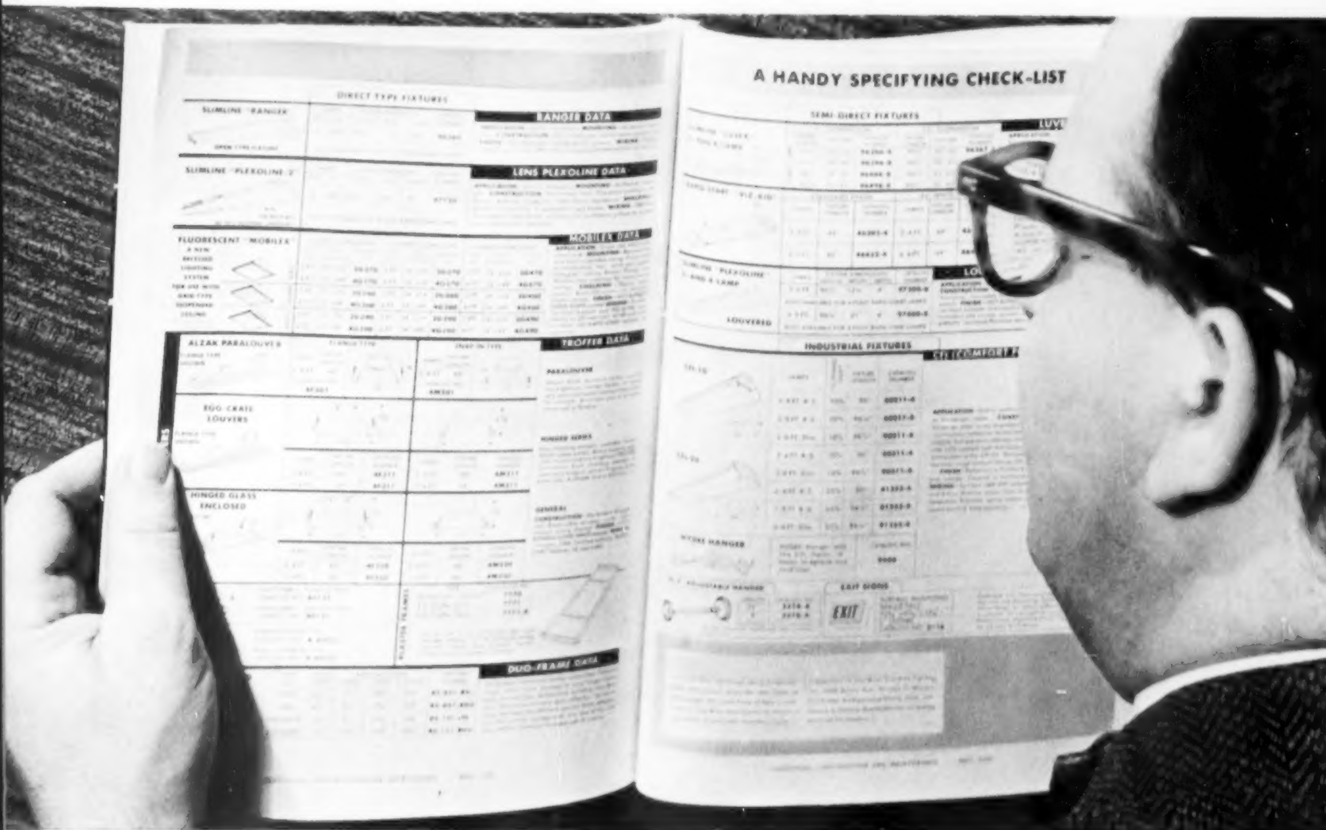
Number and Type Lamp	Weight (lbs)	Line Current (amps)	Power Consumed (W	
			Ballast	Per L
For 60-cycle, 110-125 Volt Circuits				
2 – 20	3¼	.42	9	2
2 – 30	6¼	.70	18	
2 – 40	6¼	.85	15.5	
2 – 40 RS	5½	.85	17	
2 – 40 IS	11	.98	28	
2 – 48 T12	11	.98	28	
2 – 72 T12	15	1.40	33	
2 – 96 T12	18	1.75	45	
For 60-Cycle, 199-216 Volt Circuits				
2 – 40 RS				

EASY DRIVE—Thiel Tool & Engineering Co., Inc.
Easy-Eye Lighting, Inc.—see H&H Fixture Co.
EASY FLEX—Progressive Welder Sales Co.
EASY-ON—Thiel Tool & Engineering Co., Inc.
EASY-STRIP—Holub Industries, Inc.
EASY TACH—Quadrangle Mfg. Co.
Easy Washing Machine Corp., Solar, Spencer & Clinton Sts., Syracuse 1, New York
Ebco Mfg. Co., 265 N. Hamilton Rd., Columbus 13, Ohio
Ebert Electronics Corp., 212-26 Jamaica Ave., Queens Village 28, L. I., N. Y.
ECHO—Elgo Shutter & Mfg. Co.
ECLIPSE—Frick Co.
ECLIPSE—Montgomery Tool Co.
Eclipse Fuel Engineering Co., 1100 Buchanan, Rockford, Ill.
Eco Clock Co.—see Detex Watchclock Corp.
ECON—Economy Fuse & Manufacturing Co.
ECON-O-MATIC—American Pulley Co.
ECON O VAC—General Floorcraft, Inc.
ECONO-PAK—Lau Blower Co.
Economaster Sales, Inc., 120 Ninth Ave. N., Nashville, Tenn.*
ECONOMATIC—Electriglas Corp.
ECONOMATIC—Nati
ECONOMIC

COMPANY AND TRADE NAME DIRECTORY

Names and complete addresses of all manufacturers in the Product Directory listed alphabetically, together with all trade and brand names related to their products. Each trade or brand name is identified with the company claiming it.

SECTIONS WORK FOR YOU!



EPG advertising will supply product data: styles and sizes . . . performance characteristics . . . specifications and dimensions . . . applications . . . installation methods.

The ads in EPG will work for you, too! Users of the Guide will find the manufacturers' advertising an extremely valuable part of the reference. We've asked our advertisers to fill their space with detailed product information . . . specifications and application data . . . precise facts electrical men want when they make buying or specifying decisions. Here's how the advertising will be arranged:

Companies using one or more pages of advertising, or briefed catalogs, will be positioned in the PRODUCT SELECTION DATA section. Companies with advertising in this section will be identified in the Product Directory with marginal symbols, bold-face listings, and advertising page references for each product described in the advertising. This arrangement will (1) tell EPG users "who makes it," (2) refer him to product data to help him select.

A NEW FEATURE: For easier reference, all advertising in the Manufacturers' Product Data Section will be indexed according to product, at the front of the section.

Companies using less than a full page to describe individual products, will be positioned in the Product Directory adjacent to the product their advertising describes. Through this special make-up, subscribers will be able to study product details while checking sources of supply.

Keystone Aluminum Conductor System Installed at Penna. R.R. Shops

ASSURE 7 WAY SAVING IN WEIGHT...POWER...LABOR

THIS IS AN immense project—the new car repair shop of the Pennsylvania Railroad. The shop is 2760 ft. long; 15 overhead cranes are required with capacities up to 25 tons. To furnish electrical connections for the cranes two 3-rail Keystone Aluminum Conductor Systems, each running the full length of the shop, were specified and installed.

Keystone was judged best qualified to meet the rigid conditions required of this installation. It was selected because it would . . .

SAVE TRANSFORMERS—Three installations needed with steel conductors are eliminated with Keystone Aluminum Conductor System.

SAVE FEEDER RUNS—With this non-magnetic system, all but the center tap is eliminated.

SAVE BOOSTER CABLES—System capacity permits satisfactory operation ¼-mile from feeder without boosters.

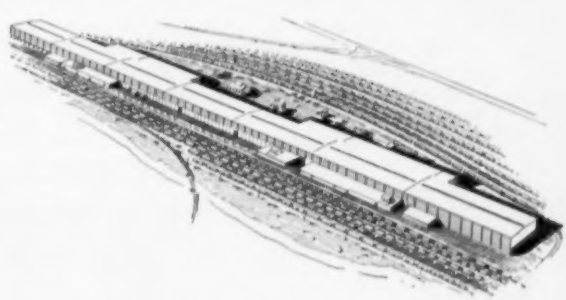
SAVE CAPACITY—Compact design permits close conductor spacings, minimizing impedence drop, reducing conductor size.

SAVE ENGINEERING COSTS—Integrated package design, factory assistance reduce time and effort.

SAVE INSTALLATION COSTS—Lightweight components, factory prefabrication, foolproof design cut erection time and cost.

SAVE OPERATING COSTS—Adequate voltage supply assures maximum crane operating speeds, reduces motor overloads. Protected contact surfaces eliminates shutdowns on exposed systems.

Keystone Aluminum Systems are now operating countrywide on AC and DC runways from 50 to 2760 ft. long, and on ore bridges and unloaders. Standard components range from 500 to 1000, 2000, 3000 and 6000 amp. capacity. Write today for case histories—*"Solving Conductor Problems."*



NEW SAMUEL REA SHOP at Hollidaysburg, Pa. where 50 steel hopper and gondola cars will be rebuilt each day. Large photo above shows 5 of the 15 overhead cranes, 2760-ft. runway; insert shows close-up of Keystone three-rail collector assembly. The Harry F. Ortlip Company of Philadelphia, specialists in railroad engineering and one of the largest electrical construction firms in the East, made the installation for Pennsylvania Railroad.

KEYSTONE

ELECTRIC SERVICE MANUFACTURING CO., PHILADELPHIA 32, PA.

sented an "Analysis of the 1937 Revision of the National Electrical Code"; "For the electrical and communication utilities, the Code does not cover electrical equipment used in generation, control, transmission, transformation and distribution, but does include electrical equipment in the plants of those utilities, which is not used primarily in performing the aforementioned franchise function. Examples of the type of electrical equipment which is included in the Code would be: lighting equipment for offices, electrical heating equipment not related to performance of the franchise function, motors for general building ventilation as contrasted with those which drive stokers for power boilers, blowers for air cooling of electrical equipment, or generators for supplying power to communication circuits, etc."

This comment undoubtedly reflects the intent of the Electrical Committee at the time this provision was formulated, and in the absence of any official interpretation I personally believe it is so accepted today. Railways were not covered in the 1937 Code but they were included in the 1940 edition and it is my opinion that the comment given above also applies to such a type of utility. Insofar as railways are concerned, it is my experience that such a type of utility does not wish to discount the importance of any Code provision and in the interests of reliability, under the conditions of use, often exceed Code requirements. Some functions of a railroad, such as signal systems, involve serious life hazards and the question of reliability often overshadows the considerations which are ordinarily covered within the scope of the Code. Electronic traffic control equipment and wiring is an electrical development of a highly complicated nature. Automation for freight yards which enables cars to establish and select their own releasing speeds in classification yards through an electronic computer is another application which I do not believe comes within the scope of the Code. In general it is my opinion that any electrical function of a railroad which concerns the traffic control of cars or trains, or the wiring of cars or methods of communication, does not come within the scope of the Code. With this general concept of Code requirements I would answer your specific questions as follows:

1—Transportation yard facilities. I personally believe that floodlight-

ing of yards or the general lighting of the station including the train platform should comply with the Code. The same holds true for the lighting or heating of a yard office. Since the electrical wiring of a car is definitely excluded from Code requirements, there could be a question with respect to standby circuits which serve such wiring.

2—I am unable to visualize any special condition which would justify any divergence from Code requirements when wiring engine houses, fueling stations or locomotive washing plants for light or power.

3—I believe the lighting and power requirements for general offices should meet Code requirements.

4—Leased warehouses should comply with Code requirements.

5—Railroad owned and operated freight warehouses should comply with Code requirements insofar as the light and power requirements are concerned.—B.A.McD.

Emergency Power

Q. *We are installing a gasoline engine driven generator in a hospital as an emergency source of power. The unit came equipped with a regular automobile type storage battery for providing the starting current and we are installing a low voltage transfer switch which will actuate the unit and transfer the load on the emergency circuits from the utility service to this generator. Now that the installation is complete, we understand we should procure a glass jar type battery as we are not supposed to use a composition encased battery for such emergency generator units. Is this a requirement of the National Electrical Code and if so, why does the Code prohibit the use of such a battery?—F.O.R.*

A. For many years the National Electrical Code has prohibited the use of automobile type batteries for either starting or ignition use on engine driven generators due both to their short life and also to the small amount of liquid capacity making it necessary to add distilled water very frequently. However, effective on May 18, 1955 this mandatory requirement was removed from the Code due to the improved construction of automobile type batteries, both regarding their life and liquid capacity. As you well know, it is now possible to buy ordinary automobile type storage batteries with from

three to five year life guarantees many of which need have distilled water added not more than twice each year. Due to this improvement in the construction and design of these batteries, the Code Committee felt it necessary to remove this requirement from the Code. Therefore it is now possible to use such batteries with emergency generators and most manufacturers of this type of equipment have been supplying these ordinary batteries with their generators since this recent change in the Code requirements.—G.R.

Two Services— One Building

Q. *I recently wired a new high school and the plans call to connect the new 200 amp load to 200 amp switch in old building which would overload the old entrance which was No. 2 wire. I told the school board I would install 400 amp service in new building and connect old building to it. The utility company told the school board they would run another 200 amp entrance, which they did. I refused to connect to this entrance. The school board hired another contractor to hook it up. These entrances are less than 30 ft apart, one in basement, one on first floor. Was I right in not connecting the setup to the new line? If I am right not connecting to this setup, whom can I contact in the State to have this code violation changed?—F.A.M.*

A. In the absence of all of the details involved with the installation, it is difficult to say who is right or wrong and if a Code violation exists. In offering the following comment I assume that the new building is an addition to the old building and is not separated therefrom by an unpierced fire wall as the Code defines a building and that the building is not classed as multiple occupancy. I also assume that the two different services have the same characteristics with respect to voltage, frequency and phase as mentioned in Section 2301-c of the Code. If the above assumptions are correct it appears that only one set of service conductors would be recognized to serve such a building, with one possible exception.

Section 2301 of the Code requires in general that a building shall be served through only one set of service conductors with three exceptions as follows:

1—Where more than one service drop is permitted by Section 2321.

2—Multiple-occupancy buildings.

3—Additional services for different classes of use.

Reference to Section 2321 covers six different conditions under which more than one service drop could be run to the same building. If the building in question is served through a transformer bank independent of the one which supplies the old building it appears to me that such procedure is recognized by the Code. If the capacity requirements make multiple services desirable, such a condition is another factor which may be considered as covered by Section 2321-c. Ordinarily services of 200 amp capacity would not be considered as qualifying for recognition under this Code provision. The rule however is very broad and it is the responsibility of the Inspector to determine from actual field conditions whether or not it should apply. Possibly some of the other exceptions covered by Section 2321 apply but from the information submitted, it appears to me that they are not involved.

Since I am not familiar with the laws of your State or any of the local laws which govern electrical installations I cannot advise the party to be contacted. It appears to me that there should be some authority who has the responsibility for determining the safety of an electrical installation and he is the one to be contacted. If there are no local laws or State provisions governing electrical installations, the Utility assumes a considerable responsibility when connecting an installation that does not satisfy Code requirements.—B.A.McD.

Receptacles

Q. *Is it true the Code prohibits the use of an extension lampcord and portable lamp containing a plug-in receptacle in the handle of the extension lamp into which a portable tool may be attached in garages?*

A. Under paragraph f.3 in Section 5105 of the Code, you will note that portable lamps used in garages must be of the unswitched type and shall not be provided with means for plug-in of attachment plugs. This has been prohibited due to the fact that for each floor at or above grade, the entire area from the floor up to a level of 18 in. above the floor is considered as a Class 1 Division 2 loca-

tion. Therefore, inasmuch as a portable lamp may be lying on the floor, the use of one containing a plug-in receptacle on the handle would be in violation of the Code as plug-in receptacles cannot be permitted within 18 in. of the floor unless they are of the explosion-proof type.—G.R.

Lighting Outlets For Baseball Field

Q. *We are installing lights at a baseball field and are wondering if we can run No. 14 wire circuits to supply individual light outlets which will be lamped with 1500-watt lights.—N.Y.G.*

A. Paragraph b. of Section 2125 will limit the load on a branch circuit supplying a 1500-watt lamp outlet to 80% of the rating of the circuit. Inasmuch as the rating of a No. 14 wire circuit would be limited to 12 amps because of this rule, it will be necessary for you to use No. 12 wire for the circuit supplying the 1500-watt lamps.—G.R.

Diesel Oil Hazard

Q. *Is diesel fuel considered hazardous to the extent explosion-proof fittings would be required? This applies to a concrete block pump house with two 20-hp transfer pumps which move fuel from outside storage tanks to locomotive fueling stands.—D.H.N.*

A. According to the National Fire Protection Association, diesel oil has a flash point of 100 F (Min or Legal). This value is minimum and may vary up to 150 F as legally established by different States. A volatile flammable liquid is one whose flash point is equal to or less than the ambient temperature. Diesel oil when used in an ambient temperature of 70 F will not volatilize and give off explosive vapors provided the oil is not heated from some other exterior source of heat. When diesel oil is used in ambient temperatures exceeding 100 F it may volatilize and produce ignitable concentrations of vapor. According to the Chairman of Panel No. 14, electrical committee of the NFPA which is concerned with the Code provisions of Articles 500 and 510; "Kerosene and diesel oil usually have flash points of about 150 F.

give your clients this **Flexibility** in **AUDIBLE SIGNALS**

specify FARADAY UNI-PACT

12 different sound instruments all fit one adapter plate

Businesses change. Noise levels go up and down. Uni-Pact signal systems let you provide for these changes . . . in advance! "Quick change" horns, buzzers, bells, chimes — from 75 to 100 decibelsNEMAStandard at 10 feet — all plug into one standard adapter plate. Safer too. No exposed terminals in dead-front adapter plate. Plan flexibility. Specify Faraday signal systems. And rely on Sperti Faraday for the best in:

Annunciators • Door Openers • Transformers • Contact Devices • Sirens Synchronous Clocks • Fire Alarm Systems • Electric Clock Sysetms • Freezer Alarms • Plugmaster Cord Sets.

Sperti Faraday Inc.

Engineers in Sound and Sight Since 1875
ADRIAN, MICHIGAN

MULTI RLM

MULTI
Lighting Equipment

see our catalog in ARCHITECTURAL FILE or write for copy

FOR SCHOOLS

FOR GYMNASIUMS
BEST FOR FLUSH MOUNTING IN SUSPENDED CEILING. SERVICEABLE FROM ABOVE OR BELOW.

FOR SWIMMING POOL
500 WATT VAPORPROOF HEAT RESISTING GLOBE.

FOR HIGH BAY GYM
RLM SPECIFICATION ALZAK FINISH ALUMINUM.

FOR FLOODLIGHTS

FOR GENERAL FLOODLIGHTING
PORCELAIN ENAMELED REFLECTOR-HEAT & IMPACT RESISTING LENS.

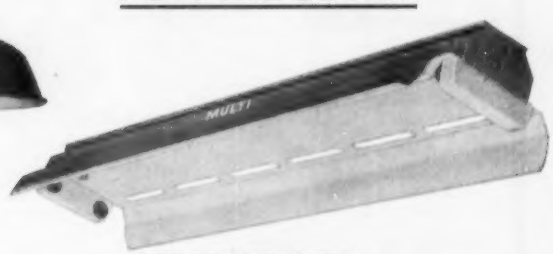
LAMPHOLDERS
FOR PAR LAMPS SEND FOR BULLETIN 555.

ALUMINUM FLOODLIGHTS
WITH ALZAK FINISH INNER REFLECTOR.

FOR INDUSTRY

RLM DOME

THREDLOK SOCKET
CHANGE A REFLECTOR LIKE YOU CHANGE A LAMP.



RLM INDUSTRIAL FLUORESCENTS WITH UPWARD LIGHT REFLECTOR.

MULTI ELECTRIC MFG. INC.
4223 W. LAKE ST. CHICAGO 24

Legal minimum flash points are established by different states, and are not less than 100 F. There are not many parts of the country where I would classify diesel oil as a volatile flammable liquid in the application of Articles 500 and 510."

To me, it appears that diesel oil is a border line case and it would be very helpful if the Code would make recommendations for correct procedure in such cases. On the installation in question I would find out the legal flash point established by the State in which the installation is located and then proceed to compare it with the maximum ambient temperatures which are involved. As an Inspector, field experience dictates that a factor of safety should be applied especially when volatile flammable liquids are concerned.—B.A.McD.

Electric Heating

Q. *We are installing electric radiant heat for a rather large amusement room and the existing service equipment does not have sufficient capacity to supply the demand load for this electric heating. This house is served by an underground service and rather than replace this, we would like to run a second separate service to supply only the new heating load being placed in this basement amusement room. Would this comply with the Code?—M.L.S.*

A. If this second service would supply all electric resistance heating built into the residence in question, the use of a separate second service would not be a Code violation as Section 2301, paragraph c. states that where additional services are required for different classes of use, the second service may be run to an individual building.—G.R.

Grounding Low Voltage Systems

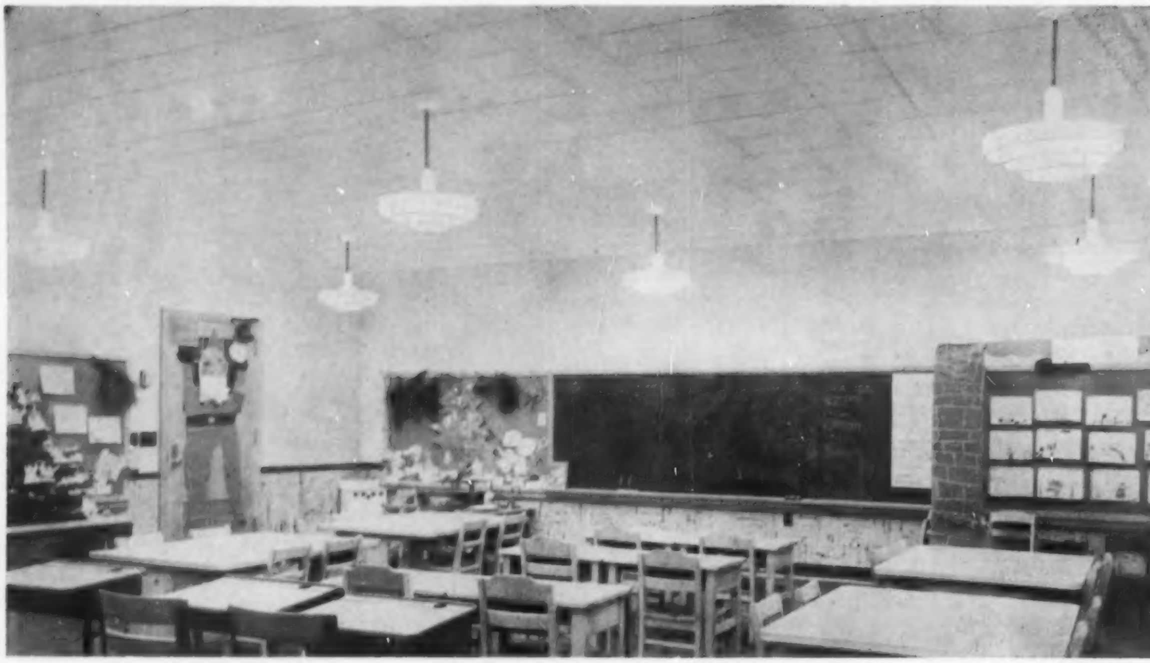
Q. *We have a large current low voltage resistive load connected to a 175 kva, 440/48-volt, single phase transformer. The transformer is fed from the 3-phase, 440-volt, 60-cycle ungrounded plant distribution system through an air circuit breaker set to trip at 150% full load current.*

It is necessary for operating per-

sonnel to come in contact with the current carrying parts of the secondary circuit. Due to production demands, it has been proposed to increase the secondary voltage to 56 volts; but an argument has arisen with some contending that over 50 volts we are exceeding code limitations. I contend that we are already doing so in that one secondary conductor is not grounded in accordance with Article 720, Section 7210, paragraph b. Am I right?—P.K.D.

A. Insofar as Section 7210-b of the Code is concerned, the 48-volt secondary obtained through the 440/48-volt transformer must be grounded when the primary circuit, either grounded or ungrounded, exceeds 150 volts to ground. This provision is also covered by Section 2517-a with an exception for portable tools as covered by Section 2545-c. Your contention in this regard is correct and may be further verified by reference to an article covering the "Philosophy of Grounding" written by L. S. Inskip, Chairman of Panel No. 5 of the Electrical Committee, National Fire Protection Association. This article appears in the January issue of the *News Bulletin* of the International Association of Electrical Inspectors, 612 N. Michigan Ave., Chicago 11, Ill. A copy may be obtained for a small fee by applying to the IAEI and I recommend it to you since this issue also covers two other articles on grounding which cover practically all of the factors involved.—B.A.McD.

CHIEF ELECTRICAL INSPECTOR William P. Hogan, of the city of Chicago, is a firm believer that good wiring installations must exceed minimum electrical code standards. Codes are minimum safety and not design or convenience standards, he advises contractors. Hogan holds regular department classes so all his inspectors gain a universal interpretation of code rules.



North Eggert School, Eggertsville, New York • Architect Duane Lyman & Assoc. • Lighting designed by E. S. Burrows

A School Problem... IN LIGHTING*

To provide recommended levels of good quality illumination in a classroom with LOW CEILINGS

THE BASIC FACTS... Classroom shown above measures 29' by 27' by 9' 3" high. Surface characteristics are as follows: White ceiling, perforated acoustic tile—80% RF; Green walls, cinder block—55% RF; Natural wood trim—40% RF; Mottled gray, asphalt tile dado—25% RF; Dark green floor, asphalt tile—10% RF†; Black chalkboard—7% RF†; Natural wood desk top—50% RF; Light tan window shades—60% RF.

†Dark floor and chalkboard not recommendations of American Standard Practice for School Lighting.

Data as reported in the February 1956 Issue of
ILLUMINATING ENGINEERING

Data submitted by Niagara, Mohawk Power Corp. shows that SILVRAY Concentric Ring Silvered Bowl Units can successfully solve problems of

LOW CEILING SCHOOL LIGHTING

THE SOLUTION... Nine pendent mounted concentric ring luminaires (Silvray Lighting, Inc. Cat. No. 1500S/3R/5) using 500-w PS-40 inside-frosted silvered-bowl lamps were suspended 24" overall, mounted 9' on centers. Average general illumination two months after installation at desk top height measured 52 footcandles.

BRIGHTNESS RESULTS

LUMINAIRE (at 45°) Maximum			650 ft-L
CEILING—Maximum	130 ft-L	Minimum	26 ft-L
FRONT WALL (between rows of luminaires)			12 ft-L
(opposite rows of luminaires)			15 ft-L
TRIM	10 ft-L	DADO	6 ft-L
FLOOR	4 ft-L	CHALKBOARD	2 ft-L
DESK TOP	25 ft-L	WINDOW SHADES	15 ft-L

For Correct School Lighting its always...

SILVRAY LIGHTING, INC.
AND ASSOCIATED COMPANIES
OFFICE: RKO BLDG., RADIO CITY, NEW YORK

In The News

Electric Heat Sparks Inspector Interest

A healthy interest in the installation and safety features of residential electric heating equipment was displayed by more than 80 electrical inspectors attending the recent 31st Annual Meeting of the Wisconsin Chapter, IAEI at the Hotel Monterey in Janesville. Program time devoted to the subject and the quality and quantity of questions asked confirmed this observation.

Inspectors' interest was based not on mere curiosity but on the realization that, in the near future, they might be called upon to approve installations of this type in their respective areas. The possibility of residential electric heating installations in some rural areas in Wisconsin looks promising at present. Test installations are already being studied on some REA lines where the Cooperative has established special trial electric heating rates of about 1.5 cents per kilowatthour. The homes under test are using a "dual-voltage controlled heat" system, according to C. F. Wright, Radiant Glass Distributors, Springfield, Ill. With such a system, homes are heated (on 240 volts) mostly when other demands are light, then time controls switch the heating load to 120 volts (one-half heat) during peak periods. Timing controls can be adjusted to suit local demand curves. By staggering drop-off and return to full-voltage operation, heat-recovery load curves can be tapered somewhat.

All electric heating installations must conform to requirements of Sections 4271 through 4286 of the 1953 Edition, National Electrical Code, Jack Kennedy, General Electric Co., told the group. Demonstrations of cable and baseboard type units included detailed discussion of design and installation practices in all types of construction. Inspectors were advised to visit cable heating jobs before the covering plaster coat is added and check minimum spacing between parallel runs of cable, distances between supporting staples, type of staples used, permanent identification tag on cable power leads and general circuiting of the installation, and whether or not the installed cable is designed for the available voltage.

NEW CHAIRMAN of the Wisconsin Chapter, International Association of Electrical Inspectors, B. R. Wisniewski, (left) of Milwaukee takes over duties of retiring chairman Rex Ridley (right) of Janesville, Wis. Election took place at annual Chapter meeting in Janesville. Both men are electrical inspectors in their respective cities and active in association work.

Similar information was presented for the baseboard and panel types of electric space heating units through display and discussion by manufacturers' representatives.

O. A. Cavanagh, service engineer, Underwriters' Laboratories, Inc., Chicago, noted that reports on heating cables listed by U.L. are available for the asking; advised that staples and staple gun heads for use with heating cable are also checked by the U.L.

Floor discussion revealed an area of confusion still exists concerning application of conduit seals to gasoline pump circuits on dispensing islands. A relatively new explosion-proof junction box with integral seals in the conduit hubs initiated the discussion. General concensus was that a need exists for more clarification of N.E.C. regulations concerning such installations.

B. F. Huffman, power use adviser, Richland Center, Wis., presented a novel live demonstration of the control of lightning discharges in rural areas through the use of lightning rods, ground rods and lightning arresters. He advised installation of grounded lightning rods in trees to prevent killing of live stock; added that

NEW CHAIRMAN of the Illinois Chapter, IAEI, Joseph N. Crosno (left) of Bloomington, Ill., receives his gavel from retiring chairman John J. Ryan of Chicago. Crosno, a power use adviser for Corn Belt Electric Cooperative, Inc., was elected to the top Chapter office at the annual meeting of the Illinois electrical inspector group in Chicago.

ground rods could be laid in trenches in fairly shallow soil with hard rock base.

The remainder of the two-day session was devoted to Chapter business and discussions of National Electrical Code revisions, local code problems and a review of the Wisconsin State Electrical Code. Delegates present voted a recommendation for revision of the Wisconsin Code to conform to the new 1956 NEC when published and appointed working committees to help in the gigantic task.

At the closing business session, the following Chapter officers were elected: Chairman—B. R. Wisniewski, Milwaukee; vice chairman —J. E. Morren, Oshkosh; secretary-treasurer—John E. Wise, Madison. Members of the Executive Board include: retiring Chapter chairman Rex J. Ridley, Janesville; Thomas Hosni, Jr., Milwaukee; R. J. Schnettler, Sheboygan; and Richard Van Der Meer, Kenosha. The next annual meeting will be held in Milwaukee.

F Lamp Light Output Doubled

A major "break-through" in fluorescent lamp performance has been announced by the Lamp Division of the General Electric Company. A new lamp known as the "Power Groove" is 8 ft long, 2⅛ in. in diameter with a series of deep indentations or grooves in the glass

tube. Rating is 200 watts at 1.5 amps, approximately double the light output of the 8 ft T12 rapid-start lamp at the same efficiency.

Advance announcement was made to fixture manufacturers and the industry press to encourage development of fixtures and components designs for the new light source. The new lamps are not interchangeable with existing lamps. New ballasts, lampholders and fixtures are required for their application. Sample production will be available to manufacturers for design purposes in June. Trade quantities are expected to be available for 1957 installation.

Japanese Electrical Contractors Visit U. S.

Twelve Japanese electrical contractors visited the United States March 2 to April 12. This group, composed of individuals engaged in management, technical operations and labor relations, formed a study team under the sponsorship of the International Cooperation Administration, Washington, D. C.

Purpose of their visit to the United States was to study and observe the construction and maintenance of transmission lines and distribution systems in this country, as well as electrical installations in industrial plants, office buildings and housing projects. Specific studies included organization and management practices,

THREAD OF A STORY or story of a thread interested M. R. O'Connor, chief engineer for Schieffelin & Co., New York City, and James Pearson, superintendent of maintenance for the Cadillac Tank plant in Cleveland, Ohio, as told by J. D. McCauley, Rigid Pipe Tools, at well-attended January Plant Maintenance Show.

ATTENDING ELECTRICAL ESTIMATING Institute at University of Wisconsin, Madison, were David H. Cochran (left), electrical estimator for E. I. du Pont de Nemours & Co., Wilmington, Del. and Wm. A. Fournier, cost engineer, engineering department, U. S. Gypsum Co., Chicago. Both men are responsible for estimating electrical system costs for new and rehabilitated plant facilities for their respective companies.

contracting methods, labor-management relations and technical operations, such as the construction, repair and maintenance of overhead and underground systems and the application of safety methods and codes. They visited with and were welcomed by American electrical contractors, public utility officials, electrical equipment manufacturers and labor union representatives, who shared their experience and technical knowledge with the group. Projects visited included the new Coliseum in New York City.

Itinerary for the study team was arranged in cooperation with American firms to enable the visitors to observe establishments whose operations are characteristic of our general working conditions, also to enable them to acquire knowledge regarding the social, cultural and economic phases of American life. The itinerary included the following electrical contractors: Emil J. Weber Elec. Co., San Francisco; Corbin-Dykes Elec. Co., Fischbach and Moore, Inc., Gannon and Watson Elec. Co., and Industrial Elec. Co., Phoenix; Buffalo Elec. Co., Inc., Buffalo; Krause & Heil, Syracuse; Fischbach & Moore, Inc., New York City.

The Japanese Electrical Contractors Study Team is the eleventh group of Japanese industrialists and technicians to come to the United States since June 1955 under the International Cooperation Administration's program of technical cooperation in Japan.

California Sticks to '37 Wire Tables

California's safety orders have not accepted the National Electrical Code carrying capacity tables since the 1937 code. As a result of a wire users committee report to the Division of Industrial Safety, A. C. Blackman, chief of the division, has stated that the findings substantiate the position of the division in retaining its safety orders ratings. He said, however, that the orders are subject to review at any time in light of new developments.

Effort to get the California safety orders to adopt the 1940 and subsequent current carrying capacity tables throughout the succeeding years has met a challenge from the division to show proof that the previous tables would cause an unsafe condition. In order to obtain actual field evidence a wire and cable users committee was appointed among California industries. These included aircraft, steel, metal trades, gas and petroleum, food processing and public buildings. Temperature tests were conducted on existing raceways for a period of over a year. More than 274 sets of surveyed data from all sections of the state were assembled. Data were taken on the most heavily loaded circuits and under the highest ambients found.

The final report of the committee recommended that (1) the present current carrying capacity tables of the electrical safety orders be retained, (2) that some restrictions or prohibitions be formulated to govern the re-use of re-installation of 600-volt wires and cables that have been withdrawn from ducts or conduits, (3) that consideration be given to further study on the several topics mentioned in the appendix to the report. These include heating in large fuse enclosures, wiring space in over current enclosures, safety switches, plastic wires and cables, conduit fittings. They are of the utmost importance and bear serious threats to safety, the committee reports.

In the interior valleys where ambient temperatures in the vicinity of the cable installations reach 100 F to 125 F, with some as high as 140 F, code grade rubber insulated cables have been used successfully on the older installations with loads near the maximum allowed by the safety orders, the report says. Cable failures reported from other causes do not seem to bear any relationship either to the current loading or temperature.

WHAT'S THE LAW?

By Jack and Michael Strauss

QUESTION: **Must an electrical contractor backfill trenches excavated by him during the course of his work?**

Mr. Boone, a general contractor engaged in the construction of a laundry building, sublet the electrical work to Homer. During the course of Homer's work, he excavated trenches so that electrical ducts might be laid. After the work was completed . . . and while the excavation dirt was still alongside the trenches . . . Mr. Boone demanded that Homer do the backfill.

"My bid said nothing about my having to do backfill", the electrician objected. "My proposal was to do the electrical work as per the plans and specifications . . . and the specifications, which were part of the general contract, provided that all refilling and backfilling, required by new construction, be performed by the contractor for general construction. That means", Homer concluded, "it's your job to backfill, not mine."

In spite of his argument, however, Mr. Boone vehemently insisted that Homer do the backfill. Reluctantly, the subcontractor complied. But, when he finished, he demanded extra compensation. When Mr. Boone refused to pay it, the irate Homer sued.

"It was part of his job to do the backfill", Mr. Boone insisted in court. "He dug out the dirt . . . he's got to put it back."

THIS WAS THE DECISION: The Court held for Homer. It said while, under ordinary circumstances, it might be expected that a contractor be required to refill excavations dug by him, such is not the case where a written agreement provides otherwise.

In this case, Homer's bid was based upon the specific provisions of the general contract and specifications . . . which provided that all filling and backfilling, required by new construction, be performed by the contractor for general construction. For doing the backfill, the court concluded, Homer, by implied contract with Mr. Boone, is entitled to the reasonable value of the extra work performed.

(Based upon a 1952 Minnesota Decision. State laws vary. For personal guidance, see your attorney.)

DATES AHEAD

Illuminating Engineering Society — Midwestern—Indianapolis, Ind., May 10-11; **Canadian** — Chateau Frontenac, Quebec, P. Q., Canada, May 17-18; and **East Central**—Shoreham Hotel, Washington, D. C., May 24-25.

International Association of Electrical Inspectors — Illinois Chapter — St. Nicholas Hotel, Springfield, Ill., May 24-25; **Ontario Chapter** — LaSalle Hotel, Kingston, Ontario, Canada, June 2; **Virginia Chapter**—Roanoke Hotel, Roanoke, Va., June 25-26; **Southern California Chapter**—San Diego, Mar. 28, Long Beach, May 23 and Santa Monica, July 25; **Southern Section**—Conrad Hilton Hotel, Dallas, Texas, October 22-24.

National Association of Electrical Distributors—48th annual convention, Ambassador-Chelsea Hotels, Atlantic City, N. J., Week of June 10.

International Home Building Exposition—New York Coliseum, New York City, May 12-20.

National Industrial Service Association, Inc.—Annual convention Bellevue Stratford Hotel, Philadelphia, Pa., May 13-17.

Pacific Coast Electrical Association, Inc.—Annual convention, Las Vegas, Nev., May 14-16.

Design Engineering Show—Convention Hall, Philadelphia, Pa., May 14-17.

Southeastern International Industrial Exposition — Lakewood Park, Atlanta, Ga., May 25.

Edison Electric Institute—24th annual convention, Atlantic City, N. J., June 4-7.

National Fire Protection Association—60th anniversary meeting, Hotel Statler, Boston, Mass., June 4-8.

NAWB CHAIRMAN, Carl Bremicker of Minneapolis, tells Chicago electrical industry representatives how Adequate Wiring is snowballing throughout the country. Mr. Bremicker made a guest appearance at the Chicago Better Wiring Conference and was chairman of the 12th Annual National Adequate Wiring Conference also held in Chicago.

PRESIDENT of the Electrical Contractors Association of Ontario is Roland L. DeMers of Windsor, Ontario, Canada. A rewiring enthusiast he has diverted the activity of his contracting firm almost entirely to upgrading wiring in existing homes and has found it to be quite profitable. Local advertising by his firm is getting better than anticipated results.

American Society of Heating and Air-Conditioning Engineers — Semi-annual meeting. The Shoreham, Washington, D. C., June 18-20.

New York State Association of Electrical Contractors and Dealers, Inc.— Annual convention, Saranac Inn, Saranac Inn, N. Y., June 24-29.

International Association of Electrical Inspectors — Section meetings: **Northwestern Section** — Newhouse Hotel, Salt Lake City, Utah, Sept. 10-12; **Southwestern Section**—Hotel and city to be announced, Sept. 17-19; **Western Section**—Statler Hotel, St. Louis, Mo., Sept. 24-26; **Canadian Section**—King Hotel, Toronto, Ontario, Canada, Oct. 12-13; **Eastern Section**—Wentworth - by - the - Sea, Portsmouth, N. H., Oct. 15-17; **Southern Section**—Statler - Hilton Hotel, Dallas, Texas, Oct. 22-24.

Illuminating Engineering Society—National Technical Conference, Hotel Statler, Boston, Mass., Sept. 17-21.

Instrument Society of America—Eleventh Annual Instrument Automation Conference and Exhibit, New York Coliseum, New York City, September 17-21.

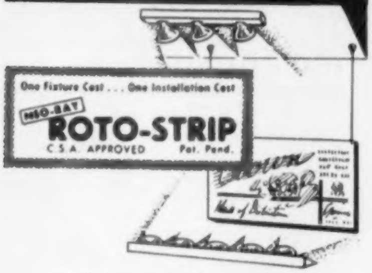
National Electrical Contractors Assn. 55th Anniversary convention and Second National Electrical Exposition, Sheraton-Palace Hotel, San Francisco, Calif., September 23-29.

National Electronics Conference—Hotel Sherman, Chicago, Ill., October 1-3.

International Association of Electrical Leagues—21st annual conference, Sheraton - Cadillac Hotel, Detroit, Mich., October 3-6.

National Electrical Manufacturers Association — Annual meeting, Traymore Hotel, Atlantic City, N. J., November 12-16.

for LIGHTING SIGNS



Indoors or outdoors . . . Roto-Strip is ideal for lighting signs. Illustration shows 5-light floor mounted and 3-light ceiling mounted Roto-Strip beaming light at sign from all angles.

This complete shallow unit (available for surface, corner or recessed mounting) has built-in recessed roto sockets that swing 90° in all directions through a complete 360° circle . . . and stay put at any angle. Available in stock sizes of 2′-3′-5′ and 8′ lengths.

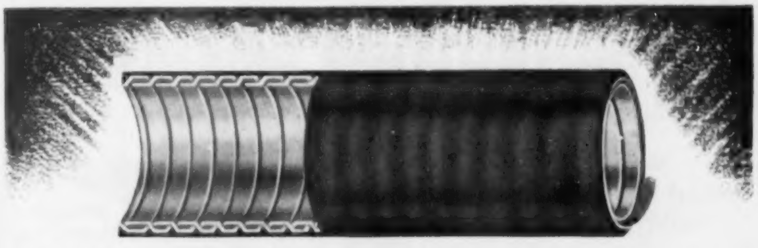
Send For Complete Catalog No. 541B • *Sold Through Wholesale Distributors*

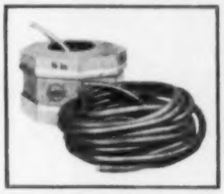
MANUFACTURERS OF LIGHTING FIXTURES INCLUDING:

Louvred Ceilings • Roto-Strip • Luminette • Kleen-VU

NEO-RAY PRODUCTS, Inc.
315 East 22nd St • New York 10 N Y

LIQUATITE The New Flexible Conduit that Protects Wiring Against Liquids and Vapors





LIQUATITE'S special pay-out carton has been developed to eliminate knots and tangles and prevent injury to conduit strewn around the floor.

LIQUATITE, the Machine Tool Gray Liquid-Tite Flexible conduit, not only gives the protection of rigid conduit but also is coated with a vinyl plastic extruded cover that resists chemical action and abrasion.

Then, too, the flexibility of LIQUATITE compensates for equipment motion and vibration as well as making it easy to use in hard-to-get-at places.

All of these factors coupled with positive seal that locks out oil, chemicals, water, grease, dust, and injurious vapors combine to insure tight, dry electrical raceways that eliminate costly shorts, burnouts and down time.

Although Machine Tool Gray is the standard LIQUATITE color it is also available in all other colors as well as black or white on special order.

LIQUATITE

ELECTRI-FLEX COMPANY
ROSELLE • ILLINOIS

MINERALLAC "PULL-IN" COMPOUND No. 100

LISTED and APPROVED by UNDERWRITERS LABORATORIES

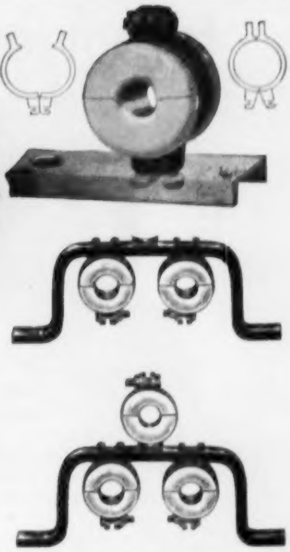
For Rubber, Synthetic, Plastic or Lead-Covered Wires or Cables

Approved by Underwriters Laboratories for lubricating wires and cables to facilitate pulling them into conduits. Not injurious to wire or wire covers. Free of objectionable odors. White in color. Will not drip or run. Convenient pint, quart, ½ gal., gal. and 5 gal. cans. Available through your electrical jobber.

MINERALLAC ELECTRIC COMPANY
25 North Peoria Street, Chicago 7, Illinois

MINERALLAC

For QUICK, EASY, SAFE Cable Installation "EFFICIENCY" NESTED CONDUCTOR RACKS



Efficiency Nested Conductor Racks are simple, compact and are scientifically designed to carry conductors equidistant from center to center. One bolt supports the bushings, and clamps the bushing support to the frame. Available in 2-3-4-5- and 6-bushing racks.

Write for Catalog 38-A

"EFFICIENCY" DEVICES FOR CONDUIT and CABLE SUSPENSION

Efficiency EEM

MANUFACTURERS OF EFFICIENCY ELECTRICAL DEVICES FOR CONDUIT AND WIRE CABLE SUSPENSION

ELECTRIC AND MANUFACTURING CO.
EAST PALESTINE, OHIO

Among the Manufacturers

Headquarters Announcements

Cold Cathode Lighting Corp., Long Island City, N. Y.—Seymour W. Brody, vice president.

Bell Sound Systems, Inc., Columbus, Ohio—K. L. Bishop, president and general manager of this subsidiary of Thompson Products, Inc.

Compco Corp., Chicago, Ill. has purchased the lighting division of Mitchell Manufacturing Co., also of Chicago.

BullDog Electric Products Co., Detroit, Mich.—Perry M. Green, Jr., sales manager of unit-substations.

Link-Belt Co., Chicago, Ill.—Richard E. Whinrey, vice president.

Westinghouse Electric Corp., Pittsburgh, Pa. — Vice President Frank L. Snyder has been appointed to the staff of A. C. Monteith, vice president in charge of the apparatus products division. John H. Chiles, division manager and M. E. Fagan, Jr., engineering manager of the transformer division.

Minnesota Mining & Mfg. Co., St. Paul, Minn.—L. L. Morin and J. E. Cahill, chief and assistant division engineers, electrical products group.

Southern States Equipment Corp., Hampton, Ga.—S. D. Sautel, assistant to sales manager.

C & D Batteries, Inc., Conshohocken, Pa.—Henry E. Jensen, vice president in charge of engineering and marketing.

Universal Motor Co., Oshkosh, Wisc.—James J. Youngworth, technical sales and service coordinator for power plants.

Great Western Div., Interlectric Corp., Warren, Pa.—will market a full line of incandescent and fluorescent lamps.

Miller Company, Meriden, Conn. —John J. Neidhart, applications engineer for lighting products.

Ward Leonard Electric Co., Mount Vernon, N. Y.—George M. Stapleton, vice president and manager of dimmer sales.

Electro Silv-A-King Corp., Chicago, Ill.—Edward Krok, vice president in charge of liaison.

Regional Appointments

NEW ENGLAND

Thomas & Betts Co.: Eugene McGrane, district manager at Boston.

CONTINUITY of LIGHT AND POWER for the Plant Maintenance Show was the responsibility of electrical contractor Charles Tull of Philadelphia, who assigned superintendent John R. Anderson (above) and competent staff to this important task.

Miller Co.: Robert W. Ellis, sales representative for eastern Massachusetts, Maine, and part of New Hampshire. Headquarters located in Lexington, Massachusetts.

Thomas Tool & Die Co.: H. A. Maggiore & Son, Cambridge, Mass., New England representative.

Moe Light Div., Thomas Industries Inc.: William Edwards, sales representative for central Conn., Albany, N. Y., Vermont and parts of Massachusetts and Rhode Island. Headquarters in Springfield, Mass.

MIDDLE ATLANTIC

Copperweld Steel Co.: Maskell E. Brown, sales engineer for eastern Pennsylvania, New Jersey and New York City, where his offices are located.

Prescolite Mfg. Corp.: Stan Heywood, eastern sales manager.

BullDog Electric Products Co.: H. L. Barger, Philadelphia, Pa. district manager. John H. Stewart, field engineer at New York district office.

Thomas & Betts Co.: Rex Pearson, New York district manager.

SOUTH ATLANTIC

Thomas Tool & Die Co.: Cooke & Associates, sales representatives for Florida. Offices in Clearwater.

Whitney Blake Co.: Montague H. Hicks, sales representative for Richmond, Va. area.

EAST CENTRAL

Pass & Seymour, Inc.: Marr Graper, Gulf States sales representative. Headquarters in New Orleans.

Lima Electric Motor Co.: Arthur C. Beesley, manager of new Cleveland, Ohio branch office.

Federal Pacific Electric Co.: W. M. Spahn, north central regional sales manager. Headquarters in Chicago.

Allis-Chalmers Mfg. Co.: Dean K. Steidinger, manager of Jackson, Mich. district of the company's industries group.

WEST CENTRAL

Thompson Electric Co.: Wynne Snoots Co., Dallas, sales representatives for Texas.

Graybar Electric Co.: D. B. Eardley, Salt Lake City, Utah branch manager. R. K. Charles, operating manager at Denver branch.

Miller Co.: Edward D. Heintze, sales representative for Colorado, Wyoming, eastern Nebraska and north central New Mexico. Offices in Denver.

Whitney Blake Co.: R. R. Meinert, district sales representative for the Minneapolis, Minn. area.

BullDog Electric Products Co.: A. G. Curtin, midwest regional manager. La Rue E. Hollembeak, field engineer at St. Louis, Mo. district office.

Moe Light Div., Thomas Industries Inc.: William Bassett, sales representative for parts of Iowa and Nebraska. Offices in Omaha.

Feedrail Corp.: S & W Electric Co., Denver, representatives for the Mountain States and New Mexico.

WEST

Peerless Electric Co.: Arthur O. Williams, sales engineer assigned to the San Francisco, Calif. office.

Sorensen & Co., Inc.: Julian M. Polis, manager of new sales office in Hollywood, Calif.

Moe Light Div., Thomas Industries Inc.: Rollo Hittle, sales representative for the metropolitan Los Angeles, Calif. area.

HEFTY LIFT by remote control is demonstrated to Lester Mount, plant manager for Shawingan Resins Corp., Springfield, Mass., at Plant Maintenance Show in Philadelphia. Man with the finger-tip control is R. Gulnac of Yale & Towne.

SEARCHLIGHT SECTION
(Classified Advertising)
EMPLOYMENT • BUSINESS
EQUIPMENT — USED OR RESALE
OPPORTUNITIES

ELECTRIC REPAIR SHOP FOREMAN

For established firm in Southern City of 125,000. Annual volume of department around $250,000, with present trend upward, due to rapid industrial growth of area. We need a capable man with sufficient background of experience to supervise department of 18 employees. Several of present group are good lead men. You will work under department manager, to free him for expansion and improvement program under way. Our company does Contracting, a large volume of rebuilt equipment sales, and has the states largest repair shop service. Also operate two branches. We offer excellent salary and bonus arrangement plus other benefits, wonderful place to live and a chance to grow with a progressive firm. All replies kept confidential.

P-1152, Electrical Construction & Maintenance
520 N. Michigan Ave., Chicago 11, Ill.

ELECTRICAL SALES ENGINEER

Salary $450.00 to $700.00. Age 25 to 35. Will accept a trainee and/or five years sales or more experience. Prefer B.S.E.E. and/or equivalent. Products are used in terminating power cables, heavy electrical switches, oil fuse cut-outs, and splice kits for voltages from 600 to 230,000. Learn products and customers needs by working in general sales office and plant, then call on representatives and dealers to instruct in use and application of products. Location: Illinois. Send two copies of resume. State acceptable starting salary. **Confidential. No obligation.** Refer to position number J-9049

LOGSDON COMPANY
19 W. Jackson Blvd. Chicago 4, Ill.

WANTED:
ELECTRICAL DISTRIBUTION EQUIPMENT SALES REPRESENTATIVE

National manufacturer of Electrical Distribution Equipment desires experienced sales representative in Milwaukee trading area. Applicants must be acquainted with architects, engineers, industrials and utilities. Send complete resume of qualifications and experience to:
RW-1405, Electrical Construction & Maintenance
330 W. 42nd St., New York 36, New York

ELECTRICAL WIRE AND CABLE

—YOUR BEST SOURCE—
- for every industrial and power application
- Odd lengths—long and short—reasonably priced

One of the Largest Stocks in the Midwest
Let us quote on requirements—
send your inquiries
We'll also buy your Surplus
Branch Office:
Houston—Walnut 3-4580
FOR YOUR TEMPORARY NEEDS TRY OUR SURPLUS DIVISION

UNIVERSAL Wire and Cable Co.
2929 N. Paulina St. Chicago 13, Ill.
EAstgate 7-4777 Code: UNIWIRE

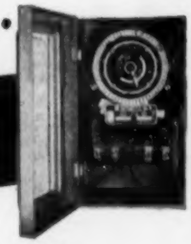
UNUSED CABLE

New rubber covered cable. 400' #4/3 conductor—133 strand Type W 600 volt cable on 36" general reel. $625 F.O.B. Chicago.

FS-1281, Electrical Construction & Maint.
520 N. Michigan Ave., Chicago 11, Ill.

ELECTRICAL CONTRACTORS ESTIMATING HANDBOOK
"A Unique Tool of the Trade"
WRITE FOR DESCRIPTIVE FOLDER TO
THE ESTIMATOR PUBLISHING CO.
4102 Wilson Road Kenosha, Wis.

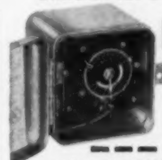
specify the finest... Light and Power
TIME SWITCHES



Before you specify *any* Time Switch check these TORK *plus-value* features!

- ✓ Skip-A-Day, Seven Day and Astronomic Timing
- ✓ Double Pole, 3 Pole and Two Circuit Switching
- ✓ Flush, Watertight and Submersible enclosures
- ✓ High Quality all-brass plates and gears
- ✓ Ratchet type dial for positive check of switching
- ✓ Motor designed for long, trouble-free service

TORK'S practical "Complete Line" provides the widest variety of timing dials, rugged switches, and all-purpose enclosures to meet any automatic ON-OFF application. TORK has been an exclusive manufacturer of high quality Time Switches for over 33 years.



PLAY SAFE • USE THE BEST

WRITE *NOW* FOR COMPLETE DETAILS and SPECIFICATIONS

Low Cost TORKMASTER #948
GUARANTEED 3 YEARS

TORK CLOCK Co., Inc.
MOUNT VERNON, NEW YORK

WHERE TO BUY

Equipment, Materials, Services and Supplies for Electrical Construction—Maintenance—Repairs

Slimline
FLUORESCENT LAMPS!
choose the best
SUPRO LUX
DEPENDABLE, TOP QUALITY, HIGH LUMEN OUTPUT, LONGER LIFE

made by
SUPRO LUX
MANUFACTURING CO., INC.
406-416 EAST 161st ST.
BRONX 51, NEW-YORK

write for our special low, quantity prices!

THIS WHERE TO BUY SECTION . . .

is a special classification for manufacturers desiring advertising in space units smaller than the minimum run of book display space. Space is available in this section in units from one to four inches. Every advertisement is indexed. This section can be used economically to promote new product users and uses, establish new sales outlets, reach the buying influences — at an extremely low cost.

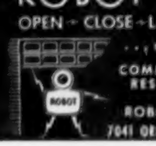
Is Contcrete Drilling One of YOUR Problems?

Does it take too much time? Cost too much? Then use the Wodack "Do-All"® Combination Hammer and Drill. Striking app. 2400 blows a minute, you can average a 3½"x½" hole a minute. Its drilling range is ¼" to 1½" dia. and to 24" depth. Remove the hammer member and use it as an electric drill (⅝"). Many accessories. Ask for Bulletin 810-EC, or call AUstin 7-9860.

WODACK ELECTRIC TOOL CORP.
4627 W. Huron St.
Chicago 44, Ill.,
U.S.A.

Our 40TH YEAR Making Wodack® Electric Tools

ROBOT OPERATORS
OPEN - CLOSE - LOCK DOORS, GATES
...Electronically



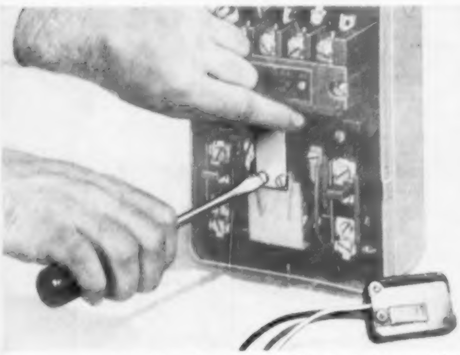
COMMERCIAL, INDUSTRIAL RESIDENTIAL & SPECIAL
Write for Catalog
ROBOT APPLIANCES, INC.
7041 ORCHARD - DEARBORN, MICHIGAN

Advertising In This Issue

• These manufacturers advertised their products in the ELECTRICAL PRODUCTS GUIDE


SQUARE D's
NEW
Unit Substation
IN POWER-STYLE CONSTRUCTION
Designed to match Square D's Power-Style switchboards and control centers, these new Unit Substations meet NEMA, ASA, and AIEE standards. Available from 75 to 500 KVA; in primary voltages up to 4800V; secondary up to 600V.
Molded case circuit breakers (*left*) up to 800 amperes and QMB Saflex fusible switches (*right*) up to 600 amperes are available in compact panel construction.
Large air circuit breaker (*above*) up to 1600 amps can be combined with a short panel in one section.
REAR VIEW
3 single phase, dry-type transformers individually mounted on base in ventilated enclosure—heating and vibration held to a minimum. Transformers easily accessible for maintenance and inspection. When no air circuit breaker or metering equipment is used, entire area at top left is available for pull box.
Pothead
Interrupter Switch
Cutout
Potheads, fused or unfused load break air-interrupter switches and fused or unfused oil-filled cutouts are available. Air-interrupter switches and cutouts are easily accessible from front of Substation.
SQUARE D COMPANY

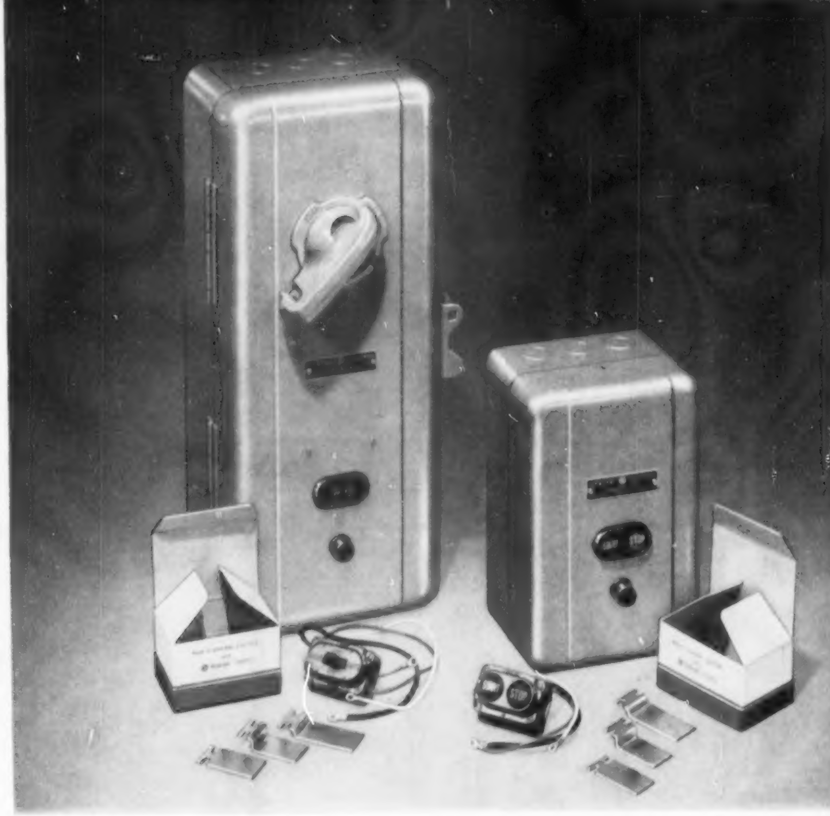
1 **Remove knockout** provided in covers of G-E starters. Knockout accommodates either push button or selector switch.



2 **Mount bracket** with two screws that hold armature stop. Select proper bracket from three provided in each kit.

3 **Mount push button,** or selector switch by slipping spring clip on back of unit over the bracket. Wire per diagram in kit.

4 **Position unit** to fit knockout. Adjustment is easy. Spring clip permits free movement of unit on mounting bracket.



TO MODIFY G-E STARTERS—

NEW G-E Pushbutton and Selector-switch Kits

Push buttons and selector switches for mounting in the covers of G-E magnetic starters are now available in kit form. Your G-E Distributor can give you off-the-shelf service on kits any time you need it. From now on starter enclosures will be furnished with a knockout in the cover. If you need to modify a starter, you can do it yourself quickly and easily.

The new kits can be used with all general-purpose non-reversing or combination non-reversing starters from Size 0 through Size 4. A single pushbutton or selector-switch kit will modify any one of these starters.

Installation is easy, as demonstrated in the photographs at left. Each kit contains a push button or selector switch, plus three mounting brackets. One of these brackets will fit the starter you plan to modify, and you simply discard the others.

No other accessories are necessary. Only two screws are used for mounting, and these are part of the starter itself. Leads are color coded for easy wiring, and diagrams are provided with each kit.

Full information on these modification kits is available from your General Electric Distributor. Contact him for details, or write to Section 733-9, General Electric Company, Bloomington, Illinois.

Progress Is Our Most Important Product

GENERAL ELECTRIC